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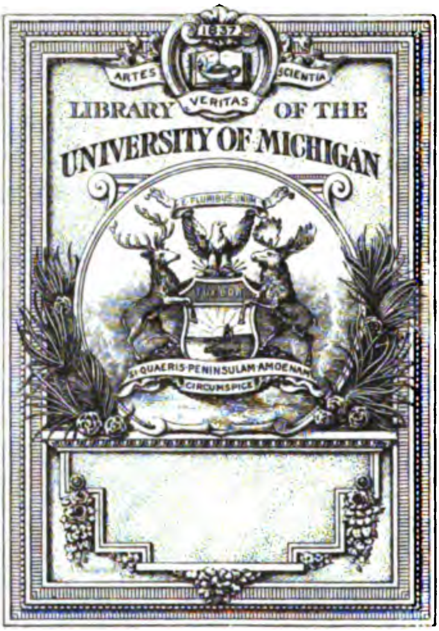
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U. S. DEPARTMENT OF AGRICULTURE.

WEATHER BUREAU.

LIGHTNING AND THE ELECTRICITY OF THE AIR.

IN TWO PARTS.

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau.

BY

1863-
ALEXANDER G. McADIE AND ALFRED J. HENRY.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Weather Bureau,
Washington, D. C., February 27, 1899.

Hon. James Wilson,
Secretary of Agriculture.

Sir: I have the honor to transmit herewith a paper entitled Lightning and the Electricity of the Air, in two parts, and to recommend its publication as a bulletin of the Weather Bureau.

Part I deals with the electrification of the atmosphere and the best methods of protecting life and property from lightning stroke, being in large part a revision of Bulletin No. 15, Protection from Lightning, the edition of which is about exhausted. Part II gives statistics of actual losses of life and property, including live stock in the fields, sustained in the United States during 1898.

The aim of the paper is to furnish information of practical value to all persons, especially those who may have occasion to seek protection from lightning.

Very respectfully,
Willis L. Moore,
Chief U. S. Weather Bureau.

Approved:
James Wilson,
Secretary.

148611

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ACKNOWLEDGMENTS.

In the following pages generous use has been made of articles published by the author in The Century Magazine, Harper's Magazine, Appleton's Popular Science Monthly, Terrestrial Magnetism, and Bulletins of the United States Weather Bureau, and a grateful acknowledgment is here made of my indebtedness to these sources. I must also acknowledge the kindness of my friend Mr. Alexander J. Wurtz, of the Westinghouse Company, who cheerfully put at my disposal his notes covering many years' experiments upon the protection of electrical apparatus from lightning.

ALEXANDER G. MCADIE.

PART I.

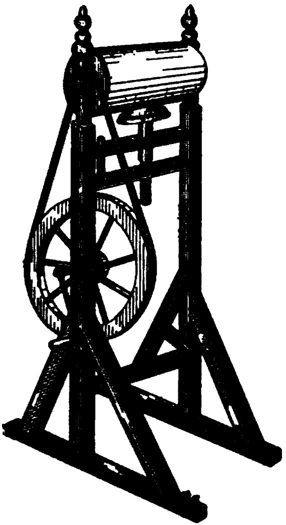
LIGHTNING AND THE ELECTRICITY OF THE AIR.

BY

ALEXANDER G. McADIE.

FRANKLIN'S KITE EXPERIMENT.

One hundred and sixty years ago a ragged colonial regiment drew up before the home of its philosopher-colonel and fired an ill-timed salute in his honor. A fragile electrical instrument was shaken from a shelf and shattered. Franklin doubtless appreciated the salute and regretted the accident. In the course of his long life he received other salutes, as when the French Academy rose at his entrance, and he constructed and worked with other electrometers; but for us that first experience will always possess a peculiar interest. The kite and the electrometer betray the intention of the colonial scientist to explore the free air, and, reaching out from earth, study air electrification *in situ*. He made the beginning by identifying the lightning flash with the electricity developed by the frictional machine of that time. A hundred patient philosophers have carried on the work, improving methods and apparatus, until to-day we stand upon the threshold of a great electrical survey of the atmosphere. It is no idle prophecy to say that the twentieth century will witness wonderful achievements in measuring the potential of the lightning flash, in demonstrating the nature of the aurora, and in utilizing the electrical energy of the cloud. The improved kite and air-runner will be the agency through which these results will be accomplished.


FRANKLIN'S ELECTRICAL MACHINE.

The famous kite experiment is described by Franklin in a letter dated October 19, 1752:

> **Make a small cross of light sticks of cedar, the arms so long as to reach to the four corners of a large, thin silk handkerchief when extended. Tie the corners of the handkerchief to the extremities of the cross, so you have the body of a kite which, being properly accomodated with a tail, loop, and string, will rise**

in the air like those made of paper, but being made of silk is better fitted to bear the wet and wind of a thunder gust without tearing. To the top of the upright stick of the cross is to be fixed a very sharp-pointed wire rising a foot or more above the wood. To the end of the twine next the hand is to be tied a silk ribbon, and where the silk and twine join a key may be fastened. This kite is to be raised when a thunder gust appears to be coming on, and the person who holds the string must stand within a door or window, or under some cover, so that the silk ribbon may not be wet; and care must be taken that the twine does not touch the frame of the door or window. As soon as the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine, will be electrified, and stand out every way and be attracted by an approaching finger. And when the rain has wet the kite and twine you will find the electric fire stream out plentifully from the key on the approach of your knuckle.

Now, how would we perform this experiment to-day, and with what results? Having flown big kites during thunderstorms, it may perhaps be best to describe step by step two of these experiments, and then speak of what we know can be done, but as yet has not been done.

Our first repetition of Franklin's kite experiment was at Blue Hill Observatory, some 10 miles southwest of Boston, one hundred and thirty-three years after its first trial. There were two large kites silk-covered and tin-foiled on the front face. These kites were of the ordinary hexagonal shape, for in 1885 Malay and Hargrave kites were all unknown to us. Fifteen hundred feet of strong hemp fish line were wrapped loosely with uncovered copper wire of the smallest diameter suitable, and this was brought into a window on the east side of the observatory, through rubber tubing and blocks of paraffin. Pieces of thoroughly clean plate glass were also used. Materials capable of giving a high insulation were not so easily had then as now. We knew very little about mica; and quartz fibers and Mascart insulators could not be obtained in the United States. Our electrometer, however, was a great improvement upon any previous type, and far removed from the simple pith-ball device used by Franklin. Knowing that an electrified body free to move between two other electrified bodies will always move from the higher to the lower potential, Lord Kelvin devised an instrument consisting of four metallic sections,

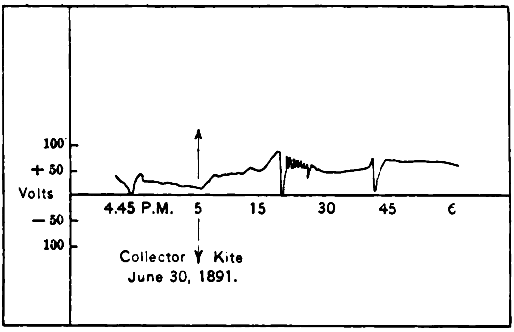
Mascart Electrometer.

symmetrically grouped around a common center and inclosing a flat free-swinging piece of aluminum called a needle. The end of the kite wire is connected with the needle and the sections or quadrants are alternately connected and then electrified, one set with a high positive potential, say 500 volts, and the other with a corresponding negative value, say 500 volts, lower than the ground.

Perhaps the most noteworthy result of these earlier experiments was the discovery (for such we think it was) that showery or thunderstorm weather was not the only condition giving marked electrical effects. The electrometer needle would be violently deflected and large sparks obtained at other times. Day after day as we flew the kite we found this high electrification of the air, and we had no trouble in getting sparks even when the sky was cloudless. One other discovery was made, and this would have delighted Franklin more than the other, for he was always most pleased when a practical application was in sight. Seated within the instrument room of the observatory, with his back to the open window through which came the kite wire carefully insulated, and the kite high in air, the

Mascart Electrometer, with Photographic Register, July, 1892.
Blue Hill Meteorological Observatory.

observer closely watching the index of the electrometer could tell positively, and as quickly as one outside watching the kite, whether it rose or fell. When the kite rose, up went the voltage, and vice versa. In other words, the electric potential of the air increased with elevation. It must be confessed that the kites made to-day would have behaved better and flown with more steadiness than the one we used. It may have been the varying wind, or more likely wrong proportions in the kite and tail; but our old hexagonal kite would dive even when high in air. Once we kept the kite aloft from the forenoon until late at night, but that was something unusual.

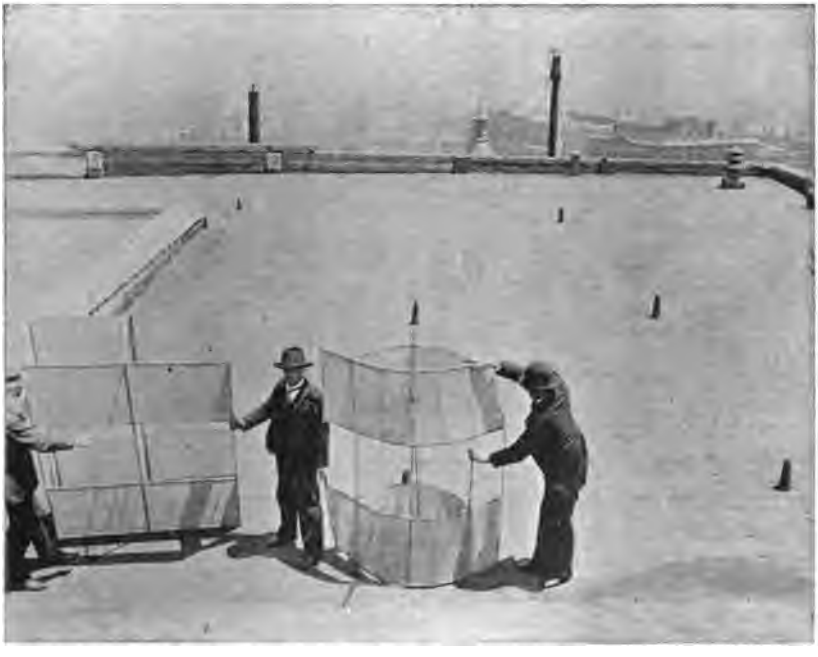


Electrical Potential of the Air. Small collector about fifteen feet from ground; kite about five hundred feet from ground.

Passing now over six years in which we had been busy measuring the electrification of the air under all conditions, and discovering, for example, that a snowstorm was almost identical with a thunderstorm in its tremendous electrical changes, we come to the year 1891, when we again flew kites for the purpose of electrically exploring the air. Our experiments at the top of the Washington Monument in 1885 and 1886 (especially those during severe thun-

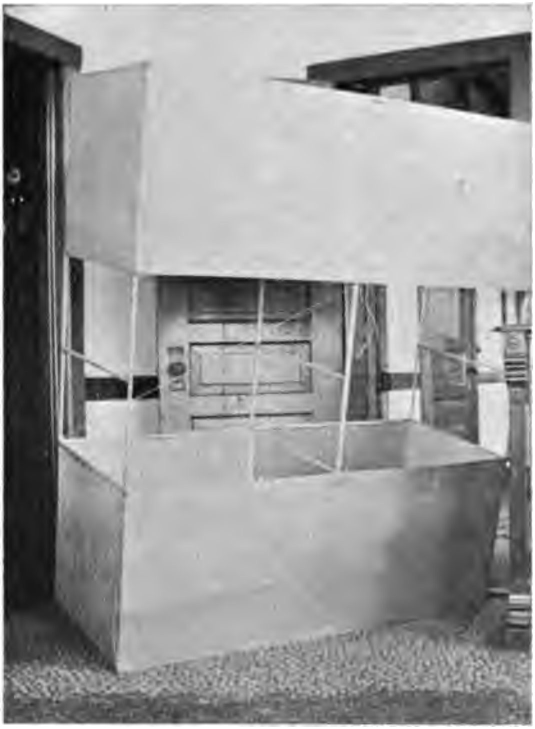
Multiple Quadrant Electrometer, July, 1892. Blue Hill Observatory.

derstorms, when we obtained potentials as high as three and four thousand volts just before the lightning), had given us an insight into the strains and stresses in the air, and taught us what to expect at such times. There was still little improvement in the kite, but much better electrical apparatus was at hand. It may seem ridiculous, but we hauled nearly a wagon load of electrical apparatus to the summit of the hill, and found occasion to use all of it. Our insulators were delicate glass vessels, curiously shaped, containing sulphuric acid, and able to hold with little leakage the highest known potentials. Besides these fine Mascart insulators, we had hundreds of distilled-water batteries and two electrometers, one a Mascart quadrant, the other a large multiple quadrant. The chief aim that year was to secure by mechanical means (discarding the photographic and eye methods) a continuous record of the potential. When we can study the potential at any moment and still have a record of it, the relation of the electricity of the air to the pressure, temperature, and moisture will be more easily investigated. Among our records that year there is one date, June 30, 1891, where a direct comparison of the electrification of the air 15 or 20 feet from the ground and at a height of about 500 feet is shown. In one, the potential was obtained by a water-dropper collector from a second-story window in the observatory, and in the other was obtained by means of the kite. It will be seen how much higher the kite values are, although the kite was a much slower accumulator of



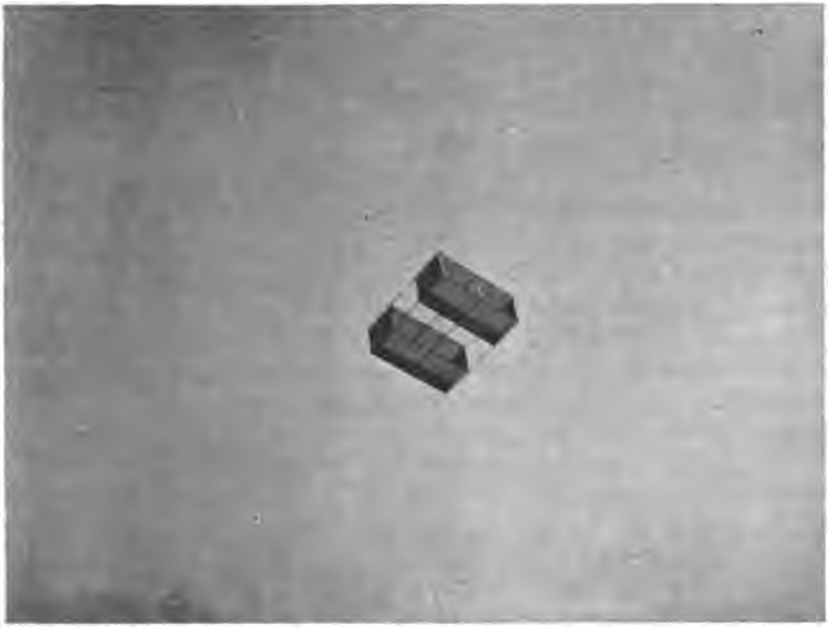
KITE-FLYING ON ROOF OF CITY BUILDING.

electricity. In the next year, 1892, the kite was flown several times during thunderstorms, but generally during afternoon storms; and in the lull preceding the wind rush the kite would fall. It was not until August 9 that we succeeded in going through a storm with the kite still flying. About 11 a. m. the kite was sent aloft, and it remained aloft until after 10 p. m. From the observatory one can see to the west 50 or more miles, and a thunderstorm came into view just about sunset. The kite was flying steadily, and whenever a finger was held near the kite wire there was a perfect fusillade of sparks. As the darkness increased, the polished metallic and glass surfaces in the large electrometer reflected the sparks, now strong enough to jump across the air gaps, and the incessant sizzling threatened to burn out the instrument. The vividness of the lightning in the west also made it plain that the storm was one of great violence, and as the observatory itself would be jeopardized, one of the four men present proposed to cut the wired string and let the kite go. But even that was easier said than done, for to touch the string was to receive a severe shock. It was necessary, however, to get out of the scrape, and one of the party took the kite string and broke the connection with the electrometer and insulators. While he was in the act of doing this,



Hargrave Kite.

the others, who by this time were outside the building, saw a flash of lightning to the west of the hill. The observer who was undoing the kite wire did not see this flash. He saw a brilliant flare up in the electrometer, and at the same instant felt a severe blow across both arms. Notwithstanding, he loosened the wire, and, dropping an end without, it took but a few moments to make it fast on the hillside some distance away from the observatory. There it remained for the rest of the night. A 105-volt incandescent lamp was placed between the end of the kite wire and a wire running to the ground. There was some light, but no incandescence of the filament. It was more in the nature of a creeping of the charge over the outer glass surface of the lamp. Stinging sparks were felt whenever the kite wire was touched. The storm gradually passed over, the lightning being vivid and frequent in the west and north, and, as we learned next day, doing considerable damage. The nearest flash to the hill, however, as well as we could determine by the interval between thunder and flash, was 4,500 feet away, so that the discharge which the observer felt while loosening the wire must have been a sympathetic one. We obtained a photograph of the prime discharge, and very curiously this shows a remarkable change of direction.



HARGRAVE KITE IN AIR. Same kite as in preceding cut.

This year, in some interesting experiments made on the roof of the Mills Building at San Francisco, it was noticed that the roof, which has a covering of bitumen, was a good insulator. Ordinarily one may touch the reel on which the kite wire is wound without being shocked, but if a wire be connected with the ventilating pipes running to the ground there are small sparks. Introducing a condenser in the circuit, the intensity of the spark is increased. It only remains to construct an appropriate coil of the kite wire and place within it another independent coil. In the outer coil a quick circuit breaker may be placed, and theoretically, at least, we shall transform down the high potential and low amperage charge of the air to a current of less potential and greater amperage. This can be put to work and the long-delayed realization of Franklin's plan of harnessing the electricity of the air be consummated.

ELECTRIFICATION OF THE ATMOSPHERE.

Franklin, in addition to many other experiments upon the electrification of the air, erected upon his house an iron rod with two bells. When the rod was electrified the bells were rung. By charging Leyden jars and testing the sign of the electrification, he came to the conclusion that " the clouds of a thunder gust are most commonly in a negative state of electricity."

A detailed history of most of Franklin's colaborers may be found in the accounts given by Exner,[1] Hoppe,[2] Mendenhall,[3] Elster, and Geitel.[4] The author[5] of this book has also given a brief summary.

The following table will give at a glance the work of the chief investigators from the time of Franklin to the end of the eighteenth century. Passing Peter Collinson, of London, who introduced to the notice of the Royal Society the experiments of Franklin, and the three less known workers—J. H. Winkler, who wrote in 1746 on the electrical origin of the weather lights; Maffei, 1747; and Barbaret, 1750—we have:

DATE.	NAME.	EXPERIMENTS.	REFERENCES.
1751	Franklin	Effects of lightning	Phil. Trans., xlvii, p. 289
1751	Mazeas	Kite experiments	Phil. Trans., 1751, 1753.
1752	Nollet	Theory of electricity	Recher. sur les causes, 1749-1754
1752	Watson	Electricity of clouds	Phil. Trans., 1751, 1752
1752	De Lor De Buffon	Iron pole 99 feet high, mounted on a cake of resin 2 feet square, 3 inches thick, Estrapade, May 18, 1752	Letter of Abbe Mazeas, dated St. Germain, May 20, 1752

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[1] Ueber die Ursache und die Gesetze der atmosphärischen Electricität. Von Prof. Franz Exner. Repertorium der Physik. Band XXII. Heft 7.

[2] Ueber Atmosphärischen und Gewitter Electricität. Meteor. Zeits. 1, 2, 3, and 4, 1885.

[3] Memoir of National Academy of Sciences.

[4] (*a*) Report of the Chicago Meteorological Congress. Part II. August, 1893. (*b*) Zusammenstellung der Ergebnisse neuerer Arbeiten über atmosphärische Electricität, Von J. Elster und H. Geitel. Wissen. Beilage zum Jahresbericht des Herzoglichen Gymnasiums zu Wolfenbüttel, 1897.

[5] (*a*) Observations of Atmospheric Electricity. American Meteorological Journal. 1887. (*b*) Terrestrial Magnetism. December, 1897.

DATE.	NAME.	EXPERIMENTS.	REFERENCES.
1752	D'Alibard	Sparks from thunder clouds, 40 foot pole in garden at Marly; also wooden pole 30 feet high, at hotel de Noailles	Mem. l'Acad. r. des Sci., May, 1762
1752	Le Monnier	Observations of air charge	Mem. de Paris, 1752
1752	De Romas	Observations of air charge; kite experiments	Mem. Sav. Etrange II, 1755
1752	Mylius Ch	Observations of air charge	8 vo, Berlin, 1752
1752	Kinnersley	Observations of air charge	Franklin's letters, Phil. Trans., 1763, 1773
1752	Ludolf and Mylius	Observations of air charge.	Letter to Watson
1753	Richman	Electrical gnomon	Phil. Trans., 1753
1753	Canton	Electricity of clouds	Phil. Trans., 1753
1753	Beccaria, G. B.	Systematic observations with an electroscope	Lett. del Elet. Bologna, 1758
1754	Lining	Kite experiments	Letter to Chas. Pinckney
1753	Wilson	Experiments	Phil. Trans., 1753, p. 347
1755	Le Roi	Experiments	Mem. de Paris, 1755
1756	Van Musschenbroek	Kite experiments	Intro. ad Phil. Nat., 1762
1759	Hartmann	Origin of electricity	
1769	Cotte	Memoirs on meteorology	Journ. Phys., xxiii, 1783
1772	Roynayne	Fog observations	Phil. Trans., 1772
1772	Henley	Quadrant electrometer	Phil. Trans., 1772
1775	Cavallo	Fogs, snow, clouds, and rain; kite experiments	Treatise on Elec., 1777
1784	De Saussure	Observations	Voyage dans les Alps
1786-7	Mann	Daily observations with an electrical machine, timing the revolutions to produce a given spark with a record of the weather	
1788	Volta	New electroscope	Lettere sulla Meteor, 1783
1788	Crosse	Experiments with collectors	Gelb. Ann. Bd., 41
1791	Reed	Insulation and conductors	Phil. Trans., 1791
1792	Von Heller	Observations	Green's Jour. d. Phys., 2 Bd., 4
1792	Schübler	Observations with weather rod	J. de Phys., lxxxiii

At the beginning of the nineteenth century, Schübler at Tübingen, systematically observed for twenty years and worked out a curve of diurnal variation. Double maxima and minima were determined; the first maximum about 8 a. m., and the second about 8 p. m. The minima occurred before sunrise and about sunset. Correlating the values with weather conditions, Schübler found in 110 cases of rain, 63 negative values and 47 positive ones; while in 33 cases of snow, 27 were positive and 6 negative.

Peltier's modification of the electroscope and his views on the origin of atmospheric electricity led to a series of observations by A. Quetelet, beginning in August, 1842, at the observatory at Brussels. After some improvements in the electroscope were made, another set of observations was made in 1844, and it appeared that no negative values were observed except during rain. Indeed, negative values were rare, only 23 cases being recorded in four years. Passing the observations made at Dublin by Clarke, in 1839, we come to those made at the observatory at Munich by Lamont, in 1850–51, with a Peltier electrometer and methods about the same as at Brussels.

The monthly and annual means are given in Poggendorff's Annalen, LXXXV, 1852, pp. 494–504, and LXXXIX, p. 258, et seq. In general, the winter months show a value nearly twice that of the summer months. About the same time, observations were made at Kreuznach by Dellmann. The yearly values nearly agree, but the mean monthly values differ considerably. A minimum occurs in May and a maximum in December. The air was generally positively electrified. Smoke and fog gave high positive values, and dust caused a change from positive to negative for several hours and to a degree exceeding the positive. Rain gave sometimes high positive and sometimes high negative, the latter often when the rain had just ended. Snow almost always gave high positive.

Everett, at Windsor, N. S., made observations, generally three per day, and the results of these and later observations have been widely published, and are too well known for extended notice now. During the same time, Wislizenus, at St. Louis, Mo., made observations, and has given the annual and diurnal curves of these. Two maxima and two minima are shown in the diurnal curve and a maximum in winter. In all, Wislizenus made some 25,000 observations, and his conclusions are therefore of more weight than those of any other observer up to that time. The normal state of the air is positive, and negative is an exceptional and temporary condition. Marked disturbances were experienced at times of thunderstorms. Fog was occasionally accompanied by negative indications, but after fine drizzling rain, fog as a rule was accompanied by positive values, often very high. A full discussion of the observations may be found in the American Meteorological Journal for 1887.

We have not space to do more than simply mention most of the other observers. W. A. Birt has given an elaborate discussion of the Kew Observations of 1845–1847 in the Report of the British Association, 1849, p. 113. At Gaud, Duprez studied the observations made from 1855 to 1864, and brings out particularly the relation to cloudiness. Palmieri, at Vesuvius, in 1850, and later with simultaneous observations at Naples and Vesuvius, found that the potential was lower at the higher station. In this conclusion he is at variance with all other observers. Some observations that are worthy of notice were made with a water-dropper collector at Pernambuco, from October, 1876, to February, 1877. On the rare occasions in which a negative potential was recorded, there were heavy rains and more or less cloudiness. We now come to the very important observations made at Paris by Mascart and others under his direction. The apparatus was installed at the College de France in February, 1879, and continuous records covering some years were obtained. In general, the potential of the air was positive. Rain was almost always accompanied by large negative values. The change in character occurs previous to the rain, and sometimes the rain is followed immediately by high positive values. A very full discussion of the observations made by the United States Signal Service is given in the Memoir of the National Academy of Sciences by Prof. T. C. Mendenhall. It is to be regretted that this discussion is not more generally known, for there are many valuable suggestions in it concerning mechanical collectors, best forms of electrometers, proper exposures, and details of methods to be followed, of great benefit to those who are to take observations. There is also an elaborate discussion of the question, "In the present state of meteorological science, can the observations of atmospheric electricity be utilized in forecasting the weather?" A very thorough set of observations was made by Müller and Leyst, in Russia, with a Carpentier form of Mascart electrometer. The mean values for bihourly observations made at Pawlowsk in 1884 are given in Annalen des Phys. Cent. Obs., Part I, 1884. Other observations are those made by C. Michie Smith, in Madras, in 1883 and 1884; Abercromby, at the Peak on the Island of Teneriffe; Dr. Fines, at Perpignan, with photographic apparatus of the Mascart pattern, which were continued for a number of years. Roiti, Magrini, and Pasquilini have two years' complete records at Florence. Exner's extensive experiments on the potential gradient, Andree's observations near the pole while on the Swedish expedition, and the work on the Sonnblick by Elster and Geitel, bring us down to the present state of the problem.

Recently experiments have been undertaken at Kew[1] to verify Exner's law, that a building reduces the potential of the air precisely as if it formed an integral part of the earth's surface. A portable electrometer was carried to five stations near the observatory, and the mean values of the several ratios found to be approximately constant. The meteorological elements are then discussed, and particularly the moisture, to see whether the potential gradient is so closely connected with the aqueous vapor as Exner claims. The results do not support the theory. The influence of bright sunshine in reducing the potential gradient, as shown by Elster and Geitel, seems more likely. The potential was lower after long sunshine. The evidence "in favor of a connection of high potential with low temperature is just about as strong as that in favor of a connection of high potential with little previous sunshine." Higher potential was found to be associated with higher pressure in the forenoon observations, but to a less marked degree in the afternoon observations. Adopting 11 miles as a limiting value of the wind velocity, it was found that with a mean velocity of 19.6 miles per hour there was a mean potential of 153, and with a mean velocity of 6.8 the mean potential was 175.

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[1] Observations on Atmospheric Electricity at the Kew Observatory. By C. Chree. Proc. Royal Soc., vol. 60.

The author does not seem to be aware of the observations made in the United States upon similar lines. An attempt was also made to investigate the relation of the potential to cyclonic and anticylonic weather. In five cases out of the seven considered the mean potential for the anticyclonic condition exceeded that for the cyclonic. In Dr. Chree's words, "There is something to be said for the hypothesis; but individual occurrences of high potential in cyclonic weather and of low potential in anticyclonic weather were not infrequent."

The recent paper of J. Elster[1] and H. Geitel is a most comprehensive review of recent investigations in the subject. For painstaking and systematic study of the potential as influenced by water vapor, sunlight, dust, and height, it cannot be excelled.

The views of von Bezold and Arrhenius concerning a photo-electric action of the solar radiation have been in part confirmed by these investigators. It has been experimentally shown that the sun's rays act on certain substances in such a way as to cause a loss of negative electricity. Our authors make the potential gradient vary with exposure to ultraviolet light. The marked disturbances occurring with precipitation are considered as disturbances of the normal field. They also think that Palmieri is right in his statement that whenever negative electricity is observed rain falls close by. Sohncke and Luvini have shown how dry ice crystals were positively electrified through friction with dust-formed water, and Maclean and Goto, and more recently Lenard and Kelvin, have discussed the question of electrification through falling water. "When waterdrops strike on a fixed moist substratum or a larger water surface the surrounding air at the time of impact shows itself as negatively electrified." And our authors think, with Lenard, that it is very probable that the negative values so prevalent during rainy weather are in part due to this. With the building of mountain observatories, the electric phenomena of the air, and more especially the silent discharges, come more readily under our observation. Elster and Geitel themselves have collected a number of observations relating to the appearance of St. Elmo's fire on the Sonnblick. It would seem that the phenomena are closely connected with climatic conditions and are to be studied in their development precisely as thunderstorms.

Elster and Geitel have rendered a great service to future students of atmospheric electricity by clearly pointing out the difference between the normal field or fair-weather electricity and the *accidental* field, if it may be so called, when the electrical measurements are greatly influenced by dust, snow, clouds, precipitation, whirling air or smoke, spattering water, etc. "Certainly it is an improvement," they say, "to diminish the influence of the lower dusty strata of air through the employment of kites, as introduced by McAdie at Blue Hill, and later by Weber at Kiel, though it is questionable if the advantage is not too dearly bought by the impossibility of determining the height." Marked improvements have been made in kite methods since these words were written. Another important matter touched upon by our authors is the circulation of electricity from the earth into the atmosphere and back again to earth. Theories are not wanting, but experimental determinations are. It is not improbable that a link in the chain of processes may be the aurora, and investigations in this direction are therefore greatly desired. Through such will the relation between the electric and magnetic fields be brought out. The following problem is suggested for investigation: "*How are the magnetic elements and the electrical currents of the air related?*"

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[1] Review of Recent Investigations in Atmospheric Electricity. By J. Elster and H. Geitel. Extract from Part II of the Report of the Chicago Meteorological Congress, August, 1893, pp. 510–522.

Professor Schuster in a recent lecture[1] has given a most interesting résumé of the experimentation of Franklin's time with the modern lecture apparatus for studying the conduction of gases. The question of the breaking down of the air as an insulating medium is touched upon, and the effect of light and of the discharge itself considered. Electric sparks are liable to succeed each other along the same path, and Schuster thinks this points to a higher conductivity of the air along the path of the previous discharge. Schuster also thinks that the location of the positive charge, corresponding to the earth's negative charge, can only be ascertained through the agency of balloon and kite experiments. "Observations made up to heights of about 1,000 feet seem to indicate a strengthening of the electric field, i. e., the fall of potential per meter is greater at a height of, say, 200 meters than on the surface of the earth." The observations of Dr. Leonhard Weber and Dr. Baschin are referred to, the former as showing how the fall of potential at a height of 350 meters was six times that at the earth's level; and the latter showing that at a height of 3,000 meters no fall could be determined, while at 760, 2,400, and 2,800 meters, respectively, the fall in volts per meter was 49, 28, and 13, respectively. It seems, therefore, likely that the lines of force of the normal electric field of the earth end within the first 10,000 or 15,000 feet. Schuster advances the somewhat startling view that the semidiurnal variation of atmospheric electricity is connected with "the same circulation in the upper regions of the atmosphere which shows itself in the corresponding changes in pressure." He refers to Exner's formula: $P = \frac{A}{I + kp_0}$, where $A = 1,300, k = 13.1, p_0 =$ pressure of aqueous vapor present, in centimeters, and $P =$ the electric force;

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[1] "Atmospheric Electricity." Lecture delivered before the Royal Institution of Great Britain, February 22, 1895, by Professor Arthur Schuster.

and notes the agreement between vapor pressures 0.23 and 0.95. It is the amount of vapor, and not the humidity, which controls. Elster and Geitel's ultraviolet radiation relation to electrification and amount of aqueous vapor present is also alluded to.

SOME MEASUREMENTS OF THE POTENTIAL OF THE AIR.

Experiments at the Smithsonian Institution.—In 1886 some investigations on atmospheric potential were undertaken at Washington, under the direction of General Hazen, Chief Signal Officer, and more immediately under the supervision of Professor Mendenhall. Experiments were made by the writer at the tower of the Smithsonian Institution. The electrical history of a summer afternoon thunderstorm may be read in the following record of the potential changes.

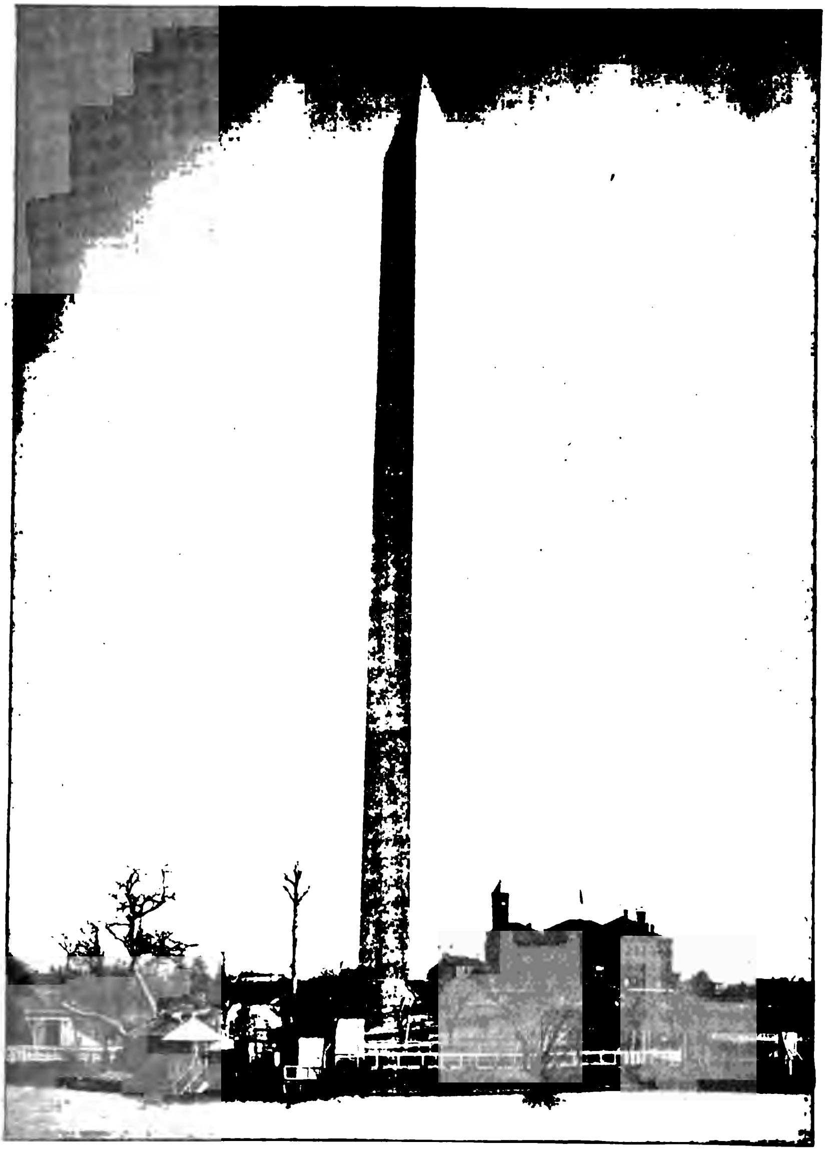
June 14, 1886; a showery and oppressive morning; the wind very light and coming in feeble puffs; southwest at 11:30 a. m.

Time.	Volts.		Remarks.
	+	−	
11:30 a. m	78		
35	54		
40	60		Wind southwest, light.
45	86		
50	54		
55	54		
58	78		
12:40 p. m	66		
45	72		
50	3		
52		66	
55		138	Wind from south-by-east, puffs, no particular cloud conditions.
57		168	
1:00		210	
02		90	Very light rain began at 1:02 p. m.
03		24	
05	120		
07	198		
09	216		Distant thunder at 1:09. Clouds in west looking like advance guard of thunderstorm, with some blue sky, however.
10	210		
11	198		
12	186		
13	156		
14	182		Thunder 1:13:25. Clouds also in northwest. Thunder from 1:16:20 to 1:17:40. Rain commenced 1:17; lasted 5 seconds.
15	108		
16	108		
17	96		
18	96		
19	78		
20	72		Rain commenced 1:20:15, light. Ended 1:22.
21	54		
21-22	54-72		Thunder at 1:22:20.
22	54		
23	30		
24	30		
25	30		
26	12		
27	6		Very light rain commenced 1:27:30.
28		12	
29		54	
30		78	
32		192	Very distant thunder.
33		246	
34		240	
35		252	
38		234	
39		180	Light rain.
40		174	Rain ended 1:39:20.
43		150	
44		120	

Time.	Volts. +	Volts. −	Remarks.
1.45 p. m.	....	72	
48	....	24	
50	12	....	
55	66	....	
58	78	....	
2:00	78	....	
01	78	....	Rain commenced 2:01 p. m.
05	78	....	
09	90	....	
10	90	....	
13	72	....	A very heavy cumulus cloud is moving up toward the place of observation from the river.
15	84	....	
17	96	....	
20	90	....	
21	66	....	
23	72	....	
25	66	....	
30	48	....	
35	48	....	
40	54	....	
45	30	....	
50	30	....	
55	24	....	
57	0.0	....	
58	....	12.0	Bright and sun shining; large, white cumulus clouds in south-southwest, southeast, and east, but the northwestern horizon is black and evidently a storm is coming.
3:00	....	114.00	
02	....	150	
03	....	186	First thunder 3:03:15 to 3:03:40; thunder 3:07:30 to 3:07:42; calm; thunder 3:09:10 to 3:09:18.
04	....	228	
05	....	276 288	
06	....	300	
07	....	312	
08	....	....	
09	....	348	Thunder 3:10:08 to 3:10:10.
10	....	360	
11	....	390	
12	....	396	Thunder 3:12:25 to 3:12:27.
13	....	420	
14	....	444	
15	....	438	Thunder 3:15:30 to 3:15:32.
16	....	444	
18	....	480 504	Thunder 3:17:30.

Experiments at the top of the Washington Monument.—The electrical history of a thunderstorm as indicated by an electrometer at the top of the monument is very interesting. The following is a description of one of many experiments thus made:

May 6, 1887. We are 500 feet above the city streets. It is a warm afternoon and looking from the west windows of the monument one sees through the near haze around Arlington and the Virginian hills far to the southwest a patch of dark cloud. It needs little experience to presage a thundersquall. It is about 20 miles away and will reach us in forty minutes, perhaps in less time. At ten minutes to three o'clock the clouds are overhead, and this is the last we shall see of the world outside until the storm is over, for it is necessary that the heavy marble door windows be swung to. All is dark in the monument save for the beam of reflected light traveling along the ground glass scale. The little mirror reflecting the light is attached to the electrometer needle, and in this way the most minute movement of the needle is made known. From the south window the nozzle of the water-dropping collector protrudes through a small opening. The wind rises,



Washington Monument. Struck June 5, 1885, and subsequently.

and we notice the needle moving steadily toward the point marked 1,000 volts, positive. This means that the pull upon the air is steadily increasing. Suddenly the needle flies to the other side of the scale and we know that the air, like a piece of over stretched rubber, has snapped and given way under the strain. The pull is now negative, i. e., in an opposite direction, and now the needle dances and we hear outside the rumble of distant thunder, all indicating the approach of the disturbance. Nearer comes the storm, if we may judge from the rapid fluctuations of the needle. Values of 3,000 and 4,000 volts are common.[1] The deflections are at times greater than the scale limits. With every flash of lightning we catch the fleeting reflection of a little spark in the electrometer. On one occasion running a wire from the iron work to within a small distance of the collector we counted more than 100 ⅛-inch sparks in a minute. If we place the eye close, but not too close, to the little peep-hole through which the nozzle goes, we shall see the stream of water twisting and breaking into spray, and each time it lightens, becoming normal quick as the flash itself, but only to rapidly twist and again distort itself.

Increase of potential with elevation.—Some idea of the normal rate of increase of potential with elevation can be gained from the following table:

Time, a day in November. The two stations about 500 *feet and* 45 *feet respectively.*

Time.	Monument.	Signal Office.	Difference.
	Volts.	*Volts.*	*Volts.*
1:30 p. m	900	216	684
1:32 p. m	888	246	642
1:34 p. m	900	216	684
1:36 p. m	862	246	616
1:38 p. m	875	240	685
1:40 p m	825	222	603

THE ELECTRICITY OF THE UPPER AIR AS MANIFESTED IN AURORAL DISPLAYS.

One of the great mysteries of the upper air is the aurora. No paper treating of the electrification of the atmosphere can be complete without a more or less imperfect résumé of our knowledge of this most beautiful of all electrical displays. The following brief review is from an article published in the Century Magazine for October, 1897, somewhat modified to suit the requirements of the present publication:

WHAT IS AN AURORA.

On the first day of January, 1892, Dr. Brendel and Herr Raschen reached the Alten Fiord, Lapland, to remain several months, studying auroral displays and magnetic disturbances. Brendel succeeded in photographing the aurora, a very difficult thing to do, as all who have attempted it know. The deep reds, which are so beautiful to the eye, make little impression on the photographer's plate, and the light itself is generally feeble and flickering. Not unaptly have the quivering auroral beams been called "merry dancers." Even the bright displays are hard to photograph, as we may see from an entry in General Greely's notebook on January 21, 1882: "A most beautiful aurora," he says, "with intense light, at times sufficiently bright to cast my shadow on the snow. Rice exposed a sensitive plate without effect, but the constantly changing position of the aurora may have been the cause."

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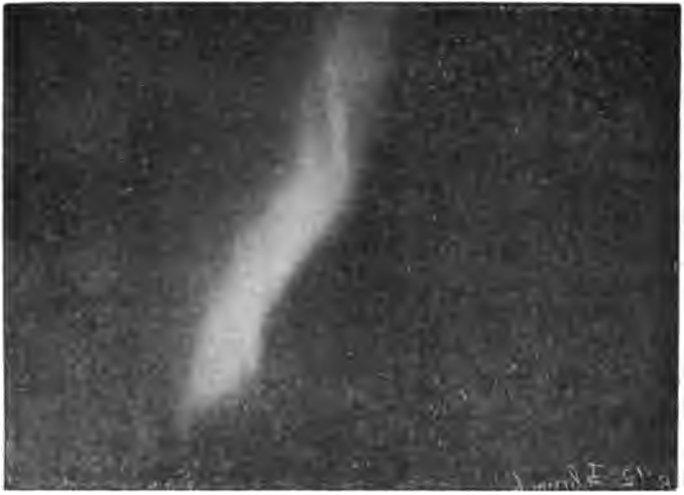
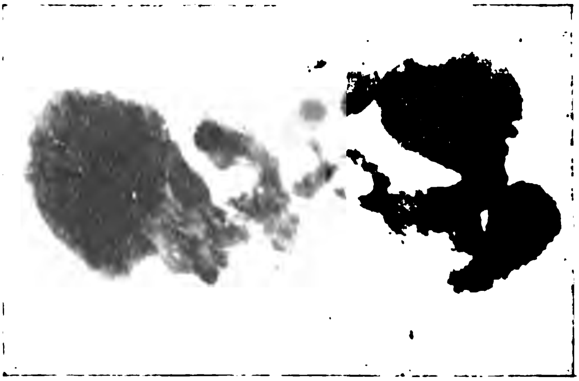
[1] At the Eiffel Tower values as high as 10,000 volts have been obtained.

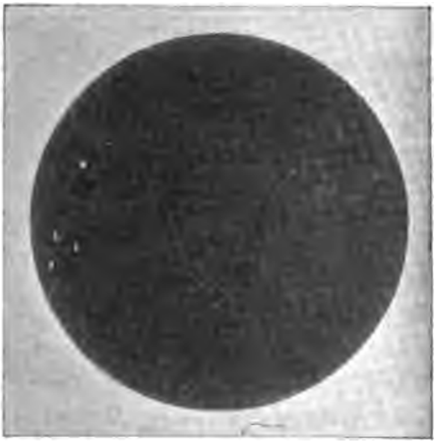


WEST END OF AN AURORAL BAND.
Photographed February 1, 1892, by Dr. Brendel, and sent by him to Mr. James P. Hall, and by him given to the writer.



PHOTOGRAPH OF SUN SPOTS OF AUGUST 8, 1893.
Made at Lick Observatory by Prof. C. D. Perrine.

Once the sun-spot period was clearly established, it was only necessary to ransack chronological lists of auroras to find how intimately auroras and sun spots were connected. Three patient investigators, Wolf, Fritz, and Loomis, soon proved that auroras were most frequent when sun spots were most numerous. The next step was to find individual relations. One bright September morning thirty-seven years ago, Carrington and Hodgson, separately studying the face of the sun, saw a remarkable outburst near the edge of a great spot. For some days the magnetometers at Kew showed unusual perturbation, and for several nights magnificent auroral displays were seen over two continents. It was long thought that a violent magnetic disturbance occurred *simultaneously* with the outburst, but recent examination of the records disproves this. In 1872 Professor Young noticed a disturbance in the chromosphere in the neighborhood of a sun spot, and upon asking the astronomers at Greenwich and Stonyhurst to examine their magnetic records, it was found that great disturbances had occurred about that time. Ten years later the astronomer at Greenwich sent out a message that read something like this: "Remarkable sun spot now visible. * * * Area of whole spot, $\frac{247}{1000000}$ of the sun's visible surface." Try to imagine what this means, and fancy yourself on the sun while that tremendous storm was in progress. We know that here on earth there was a magnetic storm with auroral displays that beggar description. Beginning a little before daylight on November 17, 1882, not a wire of the Western Union Telegraph Company could be used for three hours. The market quotations could not be sent. Late in the afternoon the trouble seemed to decrease, but at night there was a brilliant auroral display, and all telegraphic service was again interrupted. A very short cir-



PHOTOGRAPH OF SUN SPOTS OF AUGUST 29, 1893, SHOWING RELATIVE SIZE.
Made by Prof. C. D. Perrine, Lick Observatory. For purposes of illustration the spots are made white.

cuit from Boston to Dedham showed the disturbance equally with other circuits. The cables to Europe and the wires to Chicago were alike unworkable. A message was sent from Bangor to North Sidney, 700 miles, by cutting out the regular batteries and allowing the energy of nature to have its own way. The current was just as strong as if a hundred cells had been at work. At Albany the switchboard was ignited; and in telephone offices generally the annunciators dropped continually. Switchboards and wires were burned at Chicago. Incandescent lamps were illuminated in St. Paul, and even in far San Francisco the telephone operators were nigh distracted. Over half of North America, across the Atlantic, and on over northern Europe, it seemed as if legions of ethereal demons were busy inciting electric and magnetic apparatus to strange and mischievous antics.

It so happened that about the pole that year were clustered representatives from twelve nations. The Russian international expeditions were at the Lena Delta and Nova Zembla; the Norwegian at Bossekop; the Dutch at Dicksonhavn; the German at Kingua Fiord; the Finnish at Sodankyla; the Swedish at Spitzbergen; the Danish at Godthaab; the Austro-Hungarian at Jan Mayen; and the British at Fort Rae. France had two stations in the antarctic region, and our own country had the well-known Lady Franklin Bay party under Greely, and the Point Barrow party under Ray.

November 14–19, 1882, was a period never to be forgotten by these arctic prisoners. While we at home saw the display of a decade, the observers of the frozen north, turning their eyes southward or westward or eastward, saw visions glorious by *day* as well as by night, and felt perhaps some measure of recompense for their isolation and peril. Coming out of their dark quarters, they were startled and at first blinded, and General Greely writes: "The curtain appeared at one time so near our heads that Gardner and Israel speak of having unconsciously dodged to avoid it." In Ralston's diary is the entry: "The aurora appeared so low down that I raised my hand instinctively, expecting to bathe it in the light;" and Brainard relates a like impression. What a pity that under such conditions no electrometric apparatus was available. With Thomson water-dropping collectors and multiple-quadrant electrometers, records of the electrification of the lower air could have been obtained, and a few more threads raveled out from nature's tangled skein. Some observations of the potential of the air, made by Andrée, who was a member of the Swedish party at Cape Thordsen, Spitzbergen, seem to show that the electric potential diminished very rapidly during an aurora, and in fact became negative. As is well known, this same Andrée has lately attempted to reach the pole in an air ship. Not the least valuable result of the adventure will be the increase in our knowledge of the electricity of the air in polar regions We shall learn a little more about the height of auroras. We know now that while they are from 50 to 70 miles high in latitude 50°, the height decreases as we approach 68°. At Godthaab, Paulsen measured many with theodolites, and found that some were less than two-fifths of a mile high. Hildebrandsson and others have seen auroras below the clouds. Such results lead us to believe that the time is ripe to suggest a new classification of auroral displays. It has been further noticed that the colorless and quiescent auroras were *not* necessarily coincident with magnetic disturbances, while those of brilliant color and rapid change were. Many so-called auroras are probably what the Germans would call *wetter leuchten*, and akin to silent lightning.

Our little planet unquestionably responds to solar disturbances. The intense auroral displays that occur simultaneously over continents are, one may think, answering signals to the messages flashed from the sun through the quivering ether. But we may also have our own little storms and disturbances; and while appearances may be similar, the phenomena are of different origin. Some of the difficulties and discrepancies which have been met in tabulating sun spot, magnetic, and auroral phenomena can be thus explained. One wise remark by Professor Young should not pass unnoticed. "The solar tumult," he says, "may be the brother, and not the father, of our aurora." But this much is plain: the phenomena are closely allied, and mastery of the terrestrial displays will enable us to reach out and attempt the conquest of the solar ones. It may be frankly said that the man of science feels that the aurora has baffled his scrutiny.

PROTECTION FROM LIGHTNING.[1]

At the Aberdeen meeting of the British Association for the Advancement of Science Sir William Thompson made the remark, "If I urge Glasgow manufacturers to put up lightning rods they say it is cheaper to insure than to do so."

This was the answer given by practical business men, concerned only with questions of profit and loss, to the foremost physicist of our time; and their answer will serve as fairly representing views widely held, founded upon the double belief that the risk from lightning is not so very great and the protection afforded by the present methods not sufficiently certain to warrant implicit confidence and justify the necessary expense.

The recent remarkable experiments of Dr. Oliver Lodge, in his lectures before the Society of Arts, opposing and to some degree directly contradicting the empirical rules of the Lightning Rod Conference, have given support to the belief that the protection was uncertain. Indeed, realizing that his work might be misinterpreted, Lodge has stated "an idea at one time got abroad that my experiments proved existing lightning conductors to be useless or dangerous; this is an entire misrepresentation. Almost any conductor is probably better than none, but few or no conductors are absolute and complete safeguards. Certain habits of lightning rod practice may be improved and the curious freaks or vagaries of lightning strokes in protected buildings are intelligible without any blame attaching to the conductor; but this is very different from the contention that lightning rods are unnecessary and unless. They are essential to anything like security."[1]

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[1] From Bulletin No. 15, U. S. Weather Bureau.

What Lodge's brilliant experimental work does show is that the momentum of an electric current can not be overlooked in a lightning discharge. The old "drain-pipe" idea of conveying electricity gently from cloud to earth must give place to the new proposition, based upon recent discoveries, that even draining off must be done in an appropriate way to be effective. To illustrate, the rocks and trees upon a mountain side may influence and determine the course of a mountain stream, but even a good sized channel would not suffice to carry off safely an avalanche, or control the path of a landslide; so with lightning. In the past four years we have learned, through the work of Hertz and others, that when an electric current flows steadily in one direction in a cylindrical wire its intensity is the same in all parts of the wire; but if the current be of an oscillatory character, i. e., a current which rapidly reverses its direction, the condition no longer holds, and if the alternations are very rapid the interior of the wire may be almost free from current. If lightning then be a discharge of an oscillatory character, it may happen that the current down the lightning rod would be only *skin deep*. The experiments of Tesla and Elihu Thompson with currents of great frequency of alternation and very high potentials open the door to systematic study of discharges such as the ordinary lightning flash. In daily work currents of this type are coming more and more into prominence, and the time is not far distant when the lightning flash will be studied as an electrical discharge of this character. Protection entirely adequate for such discharges will then be forthcoming. Indeed, the reasons why present methods occasionally fail are now understood, and the proper remedies apparent.

LIGHTNING CONDUCTORS.

Beyond doubt, Franklin proved his case that lightning rods were efficacious in the protection of buildings. Buildings with conductors when struck by lightning suffered little damage compared with those without protectors.

EFFECT OF THE ACTION OF LIGHTNING UPON A ROD.

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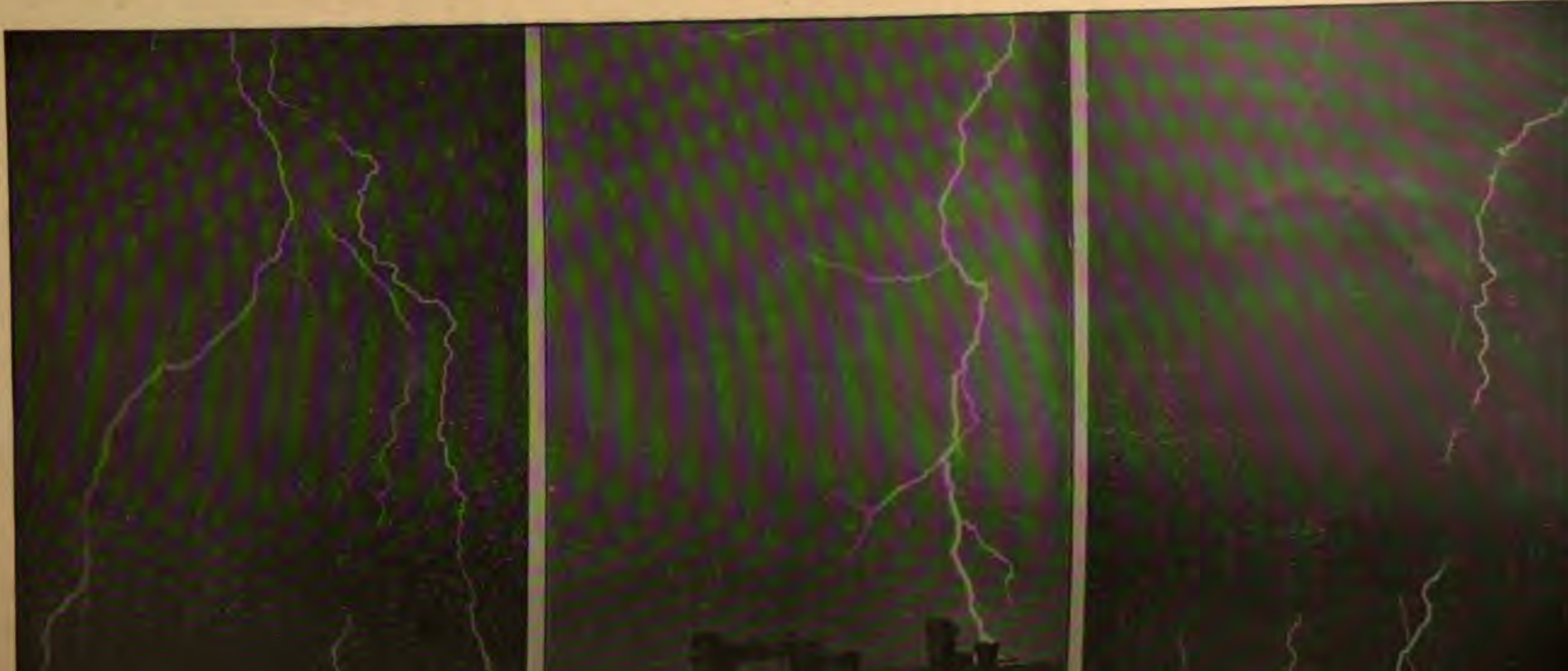
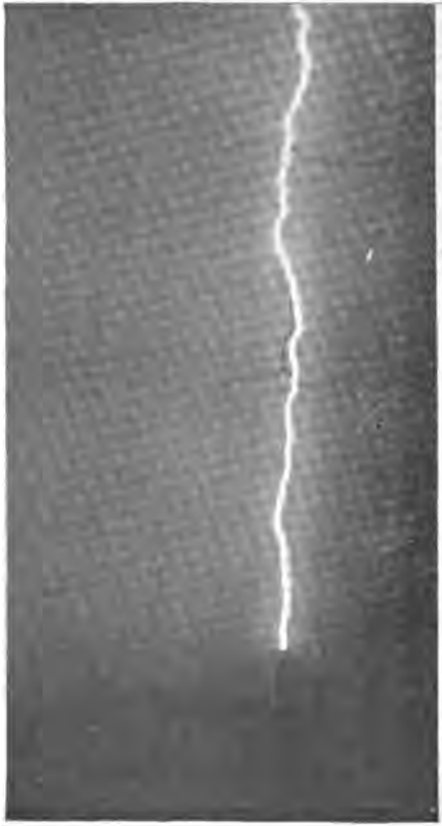
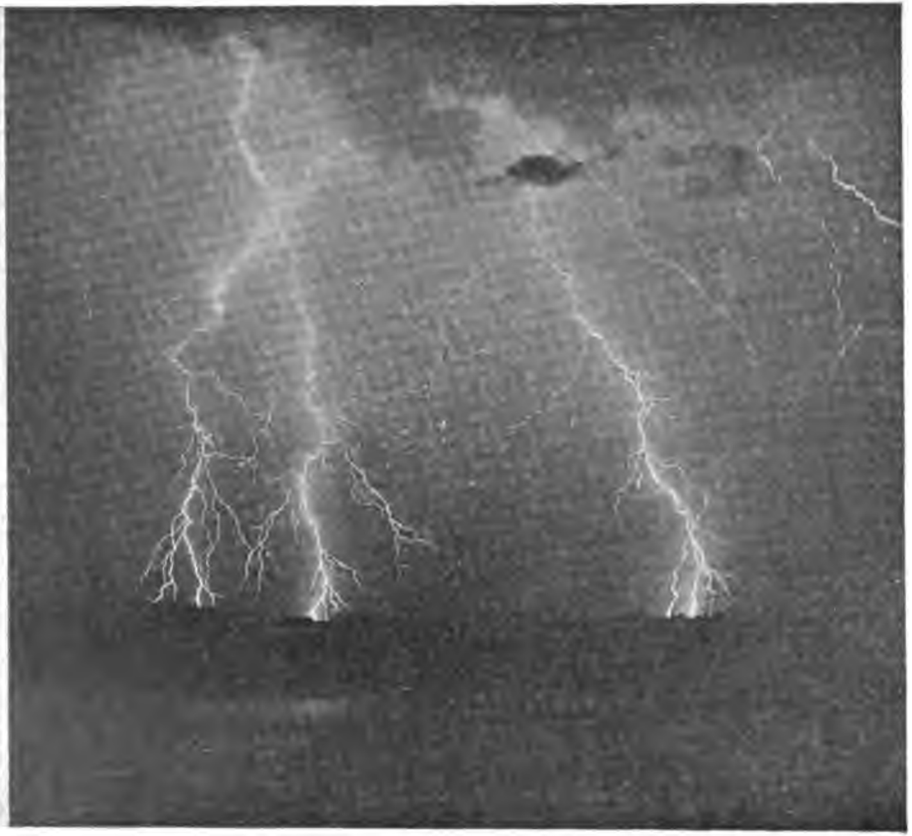
[1] Page VI. "Lightning Conductors and Lightning Guards."



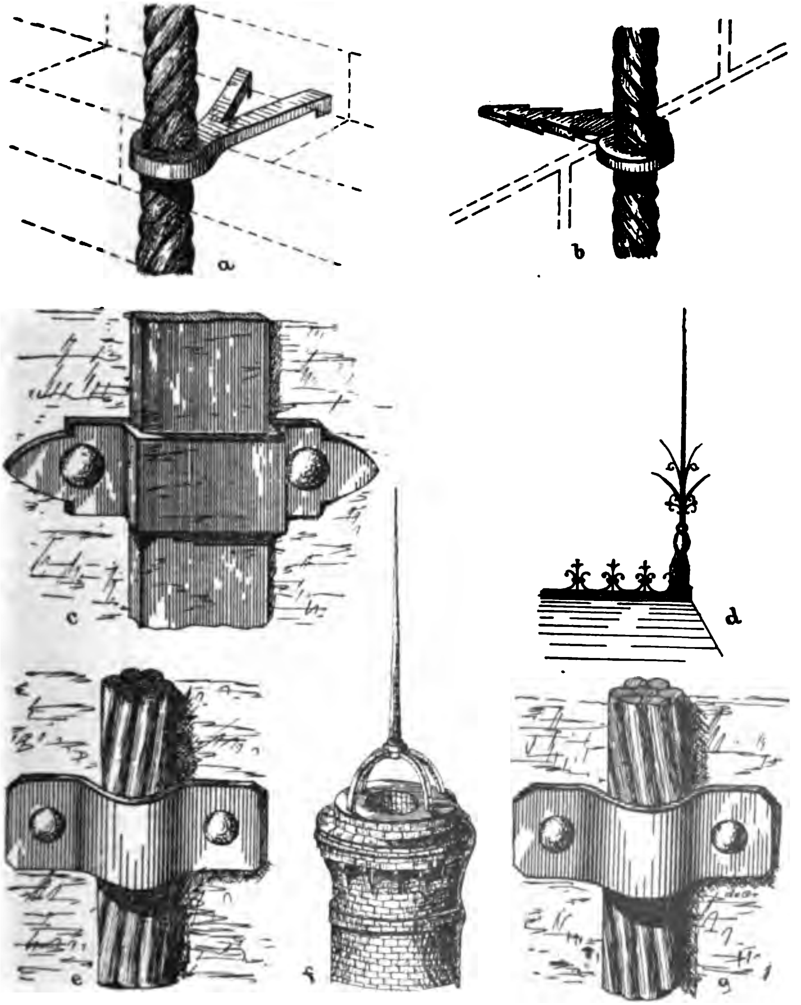


Impulsive Rush and so-called Dark Flashes.
From Popular Science Monthly, McAdie.



Multiple Flash.
From Scribner's Magazine, A. Binden.

The chief defects likely to occur are blunted points and breaks in the continuity of the connection. The function of a lightning rod is twofold; first, that of conducting the charge to earth, and second, the prevention of a disruptive discharge by silent neutralization of the cloud electrification. The latter explains why a rod terminates in a point, and likewise why points in good connection with the ground are always *desirable* upon buildings. Indeed, points are somewhat like small water pipes connected with a large reservoir. If you have enough of them and a sufficient time you may drain the largest reservoir. Furthermore, when some sudden rise or flood occurs in the reservoir, these minute drains may be of service in keeping the height of the water down.



CONDUCTORS AND FASTENINGS.
From Anderson, and Lightning Rod Conference.

In the case of lightning the points are the small escape pipes, the layer of air between cloud and earth the retaining wall, and the cloud electrification—or charge—the overflowing and destructive element. A large conductor, be it rod or tape, on the other hand is more like a large main or water way, which has its gate shut until the flood is imminent. Then the gate is suddenly opened and we try to compel the torrent to keep to the provided path. We trust in its ability to safely hold the flood. Generally it does. In perhaps nine cases out of ten, the lightning conductor, if it be such a one as we will describe later, does carry the flash to earth; but there are cases where the discharges have been heavy and overflows have resulted. To carry the lightning flash "the lightning conductor should offer a line of discharge more nearly perfect and more accessible than any other offered by the materials or contents of the edifice we wish to protect." To prevent the discharge "the conductor should be surrounded by points." These quotations are from the Report of the Lightning Rod Conference.

The statement that lightning always follows the path of least resistance, as commonly understood and stated, needs modification. True it is, that when the air is strained by being subjected to the electrifications of cloud and earth, the weakest spot gives away first, and this is apt to be in line with some small elevated knob or surface; but it is equally true, and is perhaps the more general case, that when a really vigorous disruptive discharge does occur, it is somewhat, as Dr. Lodge aptly puts it, like an "avalanche." As a matter of fact, we find from the study of actual cases where buildings have been struck, that lightning often disregards entirely metallic surfaces and points. What we should first know is, whether the condition is to be one of "steady strain,"[1] or "impulsive rush"[1] discharge. In the case of "steady strain," the metal is apt to influence the path of discharge; in the case of an "impulsive rush" discharge, even *points* seem to lose their efficiency and become of little use.

In a letter[2] of an old British admiral there occurs a description of his being called upon to approve some specifications for a lightning conductor to be erected on a certain lighthouse. He was himself a believer in the "surface" theory of Harris; but thought that, to make sure, he would go and consult his friend Faraday. Faraday, who saw only the question of conductivity in the problem, said very positively that the solid rod was better than the tube (which gives greater surface with less copper), and that *solid volume was everything*, superficial area nothing. Moreover, if Harris says otherwise "then, he knows nothing whatever about it." The admiral straightway approved the solid rod conductor for the lighthouse. Within two or three days he met Harris, and bringing up the question was told by Harris "*surface* area is most important, and if Faraday says otherwise, then he knows nothing whatever about it."

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[1] Terms used by Professor Lodge.

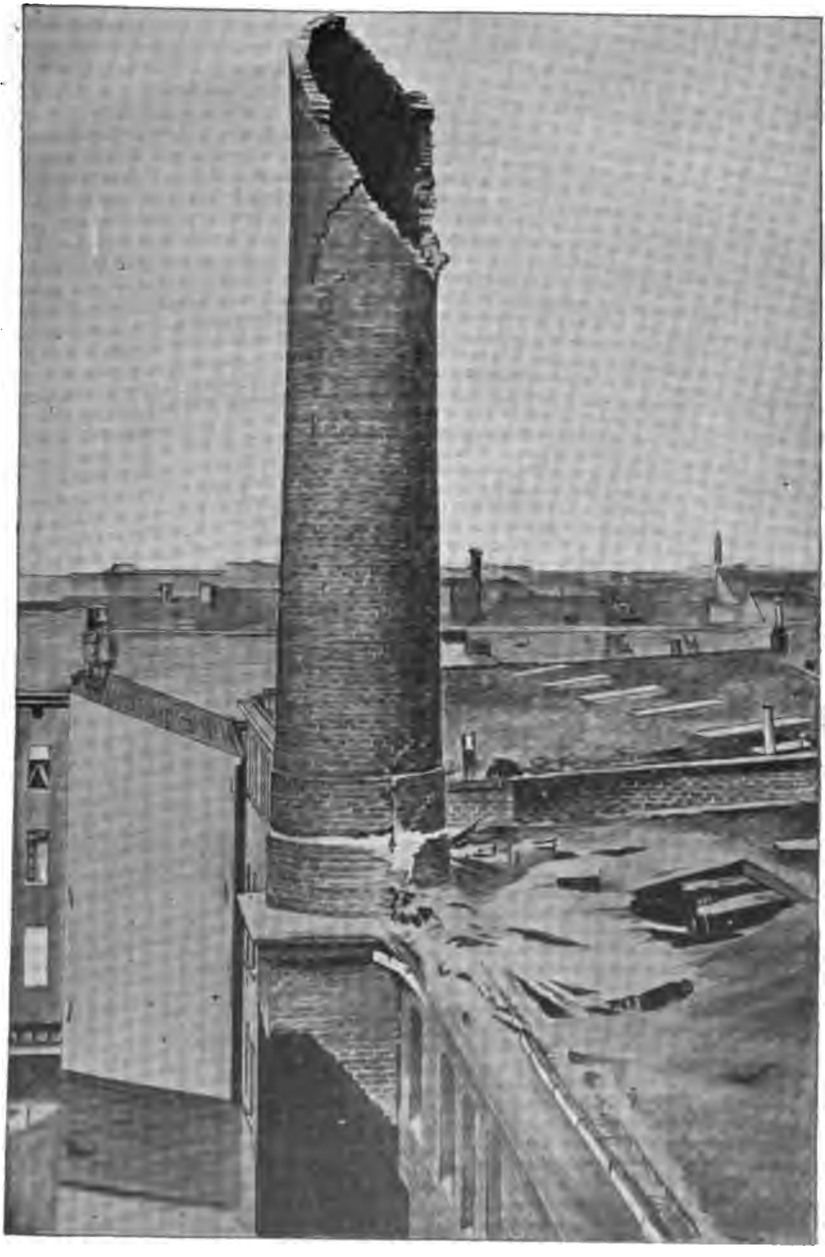
[2] See report of Lightning Rod Conference.

Up to a certain point Faraday was right; a copper rod an inch thick is capable of carrying almost any flash of lightning, and is undoubtedly a great protector, but if, as we have reason to believe, the core is seldom given a chance to carry the current, why have it? The views of Sir W. Snow Harris, based as they were upon close study of many thousand cases of lightning action, are finding in the experiments of to-day the confirmation so long needed.

While not going into details regarding this question of the shape of the rod, let us emphasize the fact, so recently brought out, that if an electric current flows steadily in one direction in a cylindrical wire, its intensity is the same in all portions of the wire, as shown by Hertz, but that with a current of an oscillatory character, i. e., a current which rapidly reverses its direction, this condition no longer holds, and if the direction is altered very rapidly the interior of the wire, in our case the lightning rod, may be almost free from current.

In 1882 appeared the report of the Lightning Rod Conference; in many respects the most important contribution to the literature of the subject yet made. While so many foreign governments, and in particular France, had by means of officially constituted boards taken a governmental interest in the protection of the people from the dangers of lightning, the English speaking people of the world aside from the few directions officially issued for the protection of magazines and lighthouses, remained without any authoritative utterance upon the subject; and while this conference itself did not have strictly official sanction, it carries, from the character of its makeup, a weight certainly as great, if not greater, than an official board. It was simply a joint committee of representative members of the Institute of British Architects, the Physical Society, the Society of Telegraph Engineers and Electricians, the Meteorological Society, and two co-opted members. As might be anticipated from such auspices, the report is an excellent one, and must stand for years as the embodiment of the most widely gathered information and well-considered decisions. The report is emphatically one based upon *experience.*

The famous free-for-all discussion which occurred at the British Association Meeting in 1888, so far as our judgment goes, simply proved that the decisions of the conference could not at present be disregarded. As the president of the meeting, Sir William Thomson said, "we have very strong reason to feel that there is a very comfortable degree of security, if not of absolute safety, given to us by lightning conductors made according to the present and orthodox rules."



CHIMNEY, STRUCK JULY 29, 1890.
From Elec. Zeits., Grebel.

There are one or two further features to which attention may be called. There are some very prevalent misapprehensions with regard to lightning. For example: that it never strikes twice in the same place; that the most exposed place is always struck; that a few inches of glass or a few feet of air will serve as a competent insulator to bar the progress of a flash that has forced its way through a thousand feet of air, etc. These are alluded to in the following general directions.

ERECTION OF RODS—GENERAL DIRECTIONS.

1. Few questions have been so thoroughly discussed from practical as well as theoretical standpoints as that of the certainty of the protection afforded by properly constructed lightning rods. All barns and exposed buildings should have lightning rods. Ordinary dwelling houses in city blocks have not the need for rods that scattered houses in the country, and especially if on hillsides, have.

2. Use a good iron or copper conductor. If the latter, one weighing about 6 ounces to the foot, and preferably in the form of tape. If iron is used, and it seems to be in every way as efficient as copper, have it in rod or tape form and weighing about 35 ounces to the foot. "A sheet of copper constitutes a conductive path for the discharge from a lightning stroke much less impeded by self-induction than the same quantity of copper in a more condensed form, whether tabular or solid.—(Sir William Thomson.)

3. The nature of the locality will determine to a great degree the need of a rod. Places apart but a few miles will differ greatly in the relative frequency of flashes. In some localities the erection of a rod is imperative; in others, hardly necessary.

4. The very best ground you can get is, after all, for some flashes but a very poor one; therefore, do not imagine that you can overdo the matter in the making of a good ground. For a great many flashes an ordinary ground suffices, but the small resistance of $\frac{1}{10}$ ohm for an intense oscillatory flash may be dangerous. Bury the earth plates in damp earth or running water.

5. "If the conductor at any part of the course goes near water or gas mains, it is best to connect it to them. Wherever one metal ramification approaches another, it is best to connect them metallically. The neighborhood of small-bore fusible gas pipes and indoor gas pipes in general should be avoided."—(Lodge.)

6. The top of the rod should be plated or in some way protected from corrosion and rust.

7. Independent grounds are preferable to water and gas mains.

8. Clusters of points or groups of two or three along the ridge rod are recommended.

9. Chain or linked conductors are of little use.

10. Area of protection. Very little faith is to be placed in the so-called area of protection. The committee that first gave authority to this belief considered that the area protected by any one rod was one with a radius equal to twice the height of the conductor from the ground. Many lightning rod manufacturers consider that the rod protects an area of radius equal to the height. The truth is that buildings are struck sometimes within this very area, and we now hold there is no such thing as a definite protected area.

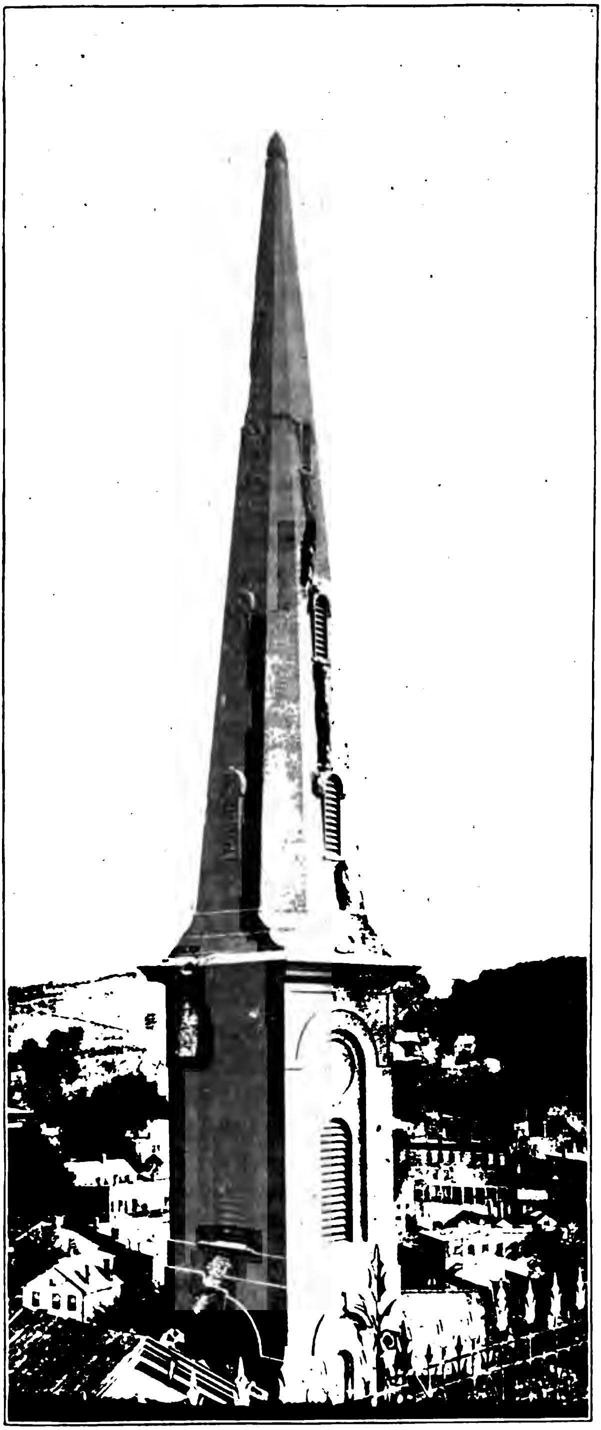
11. Return shock. Some uncertainty exists on this point. The so-called "return stroke" is caused by the inductive action of the charged cloud on bodies within its influence, and yet some distance away from the place of the direct discharge. As explained by Lord Mahon, who first called attention thereto, the sudden return of the body charged inductively to a neutral condition, following the equalization at some distant place, is the cause of the return shock. We are beginning, however, to see more clearly into the character of the stress in the dielectric, preceding and during flashes, and it is only a question of time before the use of this term, "return shock," will be abandoned. Of far greater import are the terms "recoil kick" and "alternate path," as shown experimentally by Lodge to exist.

12. Upward motion of stroke. There is no reason to doubt that the discharge takes place sometimes from earth to cloud. That is to say, that while we now consider a lightning flash as something like the discharge of a condenser through its own dielectric, made up of excessively frequent alternations, say something like 300,000 times per second, the spark, or core of incandescent air, may seem to have had its beginning at the earth's surface. That is to say, the air gap breaks down first at a point near the earth.

13. Indifference of lightning to the path of least resistance. Nearly all treatises upon lightning up to within very recent times, assumed that lightning always followed the path of least resistance. "It is simply hopeless to pretend to be able," says Lodge, "to make the lightning conductor so much the easier path that all others are out of the question." The path will depend largely upon the character of the flash.

14. Any part of a building, if the flash be of a certain character, may be struck, whether there is a rod on the building or not. Fortunately, these are exceptional instances. The great majority of flashes in our latitudes are not so intense but that a good lightning rod, well earthed, makes the most natural path for the flash. We have many instances, however (not to be confounded with cases of defective rods), where edifices, seemingly well protected, have been struck below the rods.

15. Paradox of paradoxes, a building may be seriously damaged by lightning *without having been struck at all.* Take the famous Hotel



Spire of Broadway Church,[1] Norwich, Conn., damaged by lightning July 29, 1894, 1:30 p. m. Photographed by Mr. F. J. Moulton.

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[1] The spire is of brick, 198 feet high, with a cap of brownstone. It was not protected by a lightning rod. See Scientific American, September 8, 1898.

de Ville of Brussels. This building was so well protected that scientific men pronounced it the best protected building in the world against lightning. Yet it was damaged by fire caused by a small induced spark near escaping gas. During the thunderstorm, some one flash started "surgings" in a piece of metal not connected in any way with the protective train of metal. The building probably did not receive even a side flash. This is, therefore, a new source of danger from within, and but emphasizes the necessity of connecting metal with the rod system.

16. Lightning does sometimes strike twice in the same place. Whoever studies the effects of lightning's action, especially severe cases, is almost tempted to remark that there is often but little left for the lightning to strike again. No good reason is known why a place that has once been struck may not be struck again. There are many cases on record supporting the assertion.

17. As lightning often falls indiscriminately upon tree, rock, or building, it will make but little difference sometimes whether trees are higher than adjoining buildings.

18. It is not judicious to stand under trees during thunderstorms, in the doorway of barns, close to cattle, or near chimneys and fire places. On the other hand, there is not much sense in going to bed or trying to insulate one's self in feather beds. Small articles of steel, also, do not have the power to *attract* lightning, as it is popularly put, or determine the path of discharge.

19. Unnecessary alarm. Just in advance of thunderstorms, whether because of the varying electrical potential of the air, or of the changing conditions of temperature, humidity, and pressure, and failure of the nervous organization to respond quickly, or to whatever cause it may be due, it can not be denied that there is much suffering from depression, etc., at these times. It is, perhaps, possible that these sufferings may be alleviated. Apart from this, many people suffer greatly from *alarm* during the prevalence of thunderstorms, somewhat unnecessarily, we think. Grant even that the lightning is going to strike close in your vicinity. There are many flashes that are of less intensity than we imagine, discharges that the human body could withstand without permanent serious effects. Voltaire's caustic witticism "that there are some great lords which it does not do to approach too closely, and lightning is one of these," needs a little revision in these days of high potential oscillatory currents. Indeed, the other saying, "Heaven has more thunders to alarm than thunderbolts to punish," has just so much more point to it, as it is nearer the truth. *One who lives to see the lightning flash* need not concern himself much about the possibility of personal injury from that flash.

20. Finally, if you should be in the vicinity of a person who has just been struck by lightning, no matter if the person struck appears

to be dead, go to work at once and try to restore consciousness. There are many cases on record proving the wisdom of this course; and there is reason for believing that lightning often brings about suspended animation rather than somatic death. Try to stimulate the respiration and circulation. Do not cease in the effort to restore animation in less than one hour's time. For an excellent illustration of a case of severe lightning shock and recovery, due, it would seem, to prompt action by the medical gentlemen present, all who are interested may consult the Medical News, August 11, 1888. A number of cases corroborative of this view are on record in various medical journals.

No matter which method for respiration you use, it is important to maintain the warmth of the body, by the application of hot flannels, bottles of hot water, hot bricks, warm clothing taken from bystanders, etc.

Firmly and energetically rub the limbs upward so as to force the blood to the heart and brain. If an assistant is present let him attend to this. Remember above all things that nothing must interrupt your efforts to restore breathing.

When swallowing is established a teaspoonful of warm water, wine, diluted whisky or brandy, or warm coffee should be given. Sleep should be encouraged. In brief:

1. Make the subject breathe by artificially imitating the respiratory movements of the chest.
2. Keep body warm.
3. Send for a physician.

Of the visible effects of lightning stroke upon the human body little more can be said than that sometimes burns, usually superficial have been noticed, frequently red lines or markings, which are localized congestions of the small blood vessels of the skin. These from their irregularities and branchings have led to the fanciful idea of photographs of trees, etc.

In conclusion it may be said that lightning frequently causes a temporary paralysis of the respiration and heart beat which, if left alone, will deepen into death, but, intelligently treated, will generally result in recovery.

LIGHTNING ARRESTERS.

In his Experimental Researches,[1] Faraday describes the miniature house he had built to test the question of shielding bodies from electrical influences without. It was a hollow cube twelve feet high, wound around completely on the outside with wire. He says:

> I went into this house and lived in it; but though I used lighted candles, electrometers and all other tests of electrical states, I could not find the least influ-

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[1] Paragraph 1173.

ence upon them or indication of anything particular given by them, though all the time the outside of the cube was powerfully charged, and the large sparks and brushes were starting off from every point of its outer surface.

Maxwell, in 1876, suggested to the British Association a plan based upon the experiments of Faraday for protecting a building from the effects of lightning by surrounding it with a cage of wire or rods. The problems which the electrical engineers of to-day are called upon to solve are different from those of the time of Faraday or even Maxwell. Extensive light and power plants must be guarded with great thoroughness. Cables and telegraph lines have for years been provided with various forms of lightning arresters, but only in the past five years has the action of lightning been studied with some degree of success. The chief function of all of the old style lightning arresters has been to side track the flash, switching it out of the main circuit, and leading it as quickly as possible to earth. Cable, telephone and telegraph line protection have been systematically studied of late years by Prof. Oliver L. Lodge and others. In Lodge's excellent book upon Lightning Conductors and Lightning Guards the theory of lightning arresters is given at length. Satisfactory apparatus has been devised upon sound scientific principles for the protection of the delicate galvanometers and other instruments employed on cable, telephone, and telegraph lines. The principle applied may be stated in general terms to be "a succession of air-gap paths to earth, connected up by coils of well insulated wire, across the turns of which the lightning, weakened as it is by the first air gap to earth, is not able to leap."[1]

In protecting electric light and power plants, there is the further and very important question of preventing the formation of an arc across the air gaps or at any point on the circuit, thus short-circuiting these heavy currents. Many devices exist for automatically rupturing the dynamo arc thus formed. Some have many points of excellence, but the ideal protector must not only give a proper spark gap and also rupture any arc that may form, but better still should be so designed as to prevent the formation of an arc.

Mr. Alexander J. Wurts has for many years studied the problem of protecting electrical apparatus with a great measure of success. It is known that discharges do not pass readily through coils of wire, and Wurts has found that properly constructed choke coils connected in the circuit and used with arresters form a good combination for protecting against lightning. While experimenting along these lines Wurts discovered that if the electrodes of an arrester were made of zinc, the short-circuiting arc would not be maintained. There are five metals, zinc, bismuth, antimony, cadmium, and mercury, which are non-arcing metals. For alternating currents these non-arcing arresters are quite reliable. For direct current circuits an arrester is used in which the high potential discharge is made to pass over a surface discharge plane, e. g., a pencil line upon a block of marble, and by means of a second block firmly bound to the first, the vapors from the electrodes, upon which the arc feeds, are suppressed. Wood is now used instead of marble as at first, and shallow grooves take the place of the pencil line. It is also necessary to slot the upper block at right angles. This arrester is also a discriminating arrester in that it allows disruptive discharges to pass freely, but does not allow a dynamo current to follow. These are the points dwelt upon by Wurts in a lecture given before the Franklin Institute in June, 1895.

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[1] Lightning Conductors and Lightning Guards. P. 419.

FUNDAMENTAL PRINCIPLES OF THE NONARCING RAILWAY LIGHTNING ARRESTER.

The fundamental principles of this device are based on the following facts:

1. That a static discharge will leap over a non-conducting surface, such as glass, wood, marble, etc., more easily than through an equal air space. If a pencil mark be drawn over this non-conducting surface the discharge will take place still more readily.

2. That a dynamo arc in order to be maintained must be fed by the fumes or vapors of its electrodes—conversely, therefore, that in order to avoid the formation of a dynamo arc between electrodes means must be taken to prevent the formation of these conducting fumes.

The electric crack.—An electric spark which springs across an air gap does not pass like ordinary moving matter gently pushing the air aside. Its passage is so instantaneous that the air is shattered, so to speak; the spark crashes its way through the air like a bullet through a pane of glass. If, however, the air be previously split—electrically split—the spark will pass with ease. A pencil mark over ground glass or a charred groove in a wooden surface forms an electrical crack or entering wedge through the air so that an electric discharge finds a much easier path over this surface and through this electrical crack than it does when it is forced to bore its own way through the air medium.

Discharge by disruption.—In the nonarcing railway lightning arrester the discharge is caused to pass between two brass electrodes separated by half an inch and over narrow grooves burned into a block of lignum vitae. It must not be understood that this charred surface in any way acts as a conductor in the ordinary sense of the word. The discharge takes place not by conduction, but by disruption, leaping between the electrodes and over the charred surface, the latter acting simply as an electrical crack through the air and thus greatly assisting the passage of the electrical discharge; neither does this charred surface leak dynamo current, for the ohmic resistance between the electrodes is more than 50,000 ohms. If now a solid lignum vitae block be firmly screwed down over the charred grooves and metal electrodes it will be impossible for conducting vapors to form and the device is at once a nonarcing lightning arrester.

CHOKE COILS FOR ALTERNATING CURRENT CIRCUITS.

A lightning discharge is of an oscillatory character and possesses the property of self-induction; it consequently passes with difficulty through coils of wire. Moreover, the frequency of oscillation of a lightning discharge being much greater than that of commercial alternating currents, a coil can readily be constructed which will offer a relatively high resistance to the passage of lightning and at the same time allow free passage to all ordinary electric currents.

Any coil will afford a certain amount of impedence to a disruptive discharge. Experience has shown, however, that there is one form which offers at once the maximum impedence to the discharge with the minimum resistance to the generator current.

Choke coils of this type connected in the circuit, when used in connection with nonarcing lightning arresters, offer a very reliable means of protecting well insulated apparatus against lightning. This arrangement is particularly suited for protecting station apparatus in power transmission systems. Coils can, however, be used to advantage on the line for the protection of the more expensive translating devices.

Tests made under actual working conditions indicate that for ordinary commercial voltages effective protection is obtained with four choke coils in series in each wire, with four lightning arresters intervening.

PART II.

LOSS OF LIFE AND PROPERTY BY LIGHTNING.

BY

ALFRED J. HENRY.

LOSS OF LIFE AND PROPERTY BY LIGHTNING.

There are many inherent difficulties in determining the number of lives lost by lightning in a domain so extensive as that of the United States. In the great majority of States and in all of the Territories systematic mortality returns are not made. In those States where such returns are required by local laws there is unfortunately a lack of uniformity both in the laws themselves and in their enforcement. It has been possible to obtain valuable material from the local authorities of three States only, viz, Massachusetts, Michigan, and Minnesota.

The statistics upon which this paper is based were obtained chiefly from press dispatches and manuscript reports by reliable persons.

Press dispatches are generally prepared with considerable haste and without, in some instances, sufficient time for independent verification; on the whole, however, they are fairly accurate as to the main facts, but very deficient as to important details. It would seem to be an easy matter to add a simple statement of the circumstances under which casualties by lightning occur; such, for example, as would answer the following questions: Was the person struck in a house or other building, under a tree or in the open? If in a building, was it provided with lightning rods; and, if so, were they in good condition? If under a tree, what kind of tree was it and were there other trees near by? If in an open field or road, were trees or other objects near or was the person near a wire fence?

An aggregation of facts relating to the above inquiries would enable us to speedily determine the places of danger in thunderstorms and thus minimize, in a measure at least, the loss of life by lightning.

Loss of life by lightning.—The loss of life by lightning in the United States during each month of the period 1890–1898 is shown in the table below. The number of deaths reported in 1890, the first year of the series, is considerably smaller than for any subsequent year. This fact is probably due to a lack of completeness in the early methods of collecting statistics rather than to natural causes.

The average number of persons killed annually by lightning in the United States, as shown by the figures of Table I, is 312, a number probably under rather than above the true figure. Undoubtedly a greater or less number of persons are killed by lightning each year of which there is no knowledge outside of the immediate communities in which the casualties occur. The uncertainty which attaches to the figures of the table as a result, can not easily be determined. Another cause of uncertainty, which operates, however, in a direction contrary to the one just mentioned, is the tendency to exaggeration sometimes manifest in newspaper reports. An example of gross exaggeration is afforded in the following item, clipped from the Troy (New York) Budget of September 4, 1898:

> During thunderstorms last week in Vermont two men became victims of the lightning's fury—Samuel Swan, of New Bedford, Mass., a guest at Rutland, and Dr. Royal T. Sawyer, of Worcester. These deaths make a total of twenty-nine from lightning during the past year (1898) in Vermont.

As the figures given in the above article were so much at variance with those derived from other sources, special effort was made to prove their correctness or falsity. The chief local paper of Vermont and all other available sources of information were carefully consulted, and it was found that but *five* persons were positively known to have been killed in Vermont during the year. It is but fair to The Budget to say that the item was copied from an exchange. Anyone who has had experience in newspaper work will recognize at once the utter futility of attempting to trace a paragraph of this nature to a responsible head.

In the beginning of this investigation it was thought possible to obtain an idea as to the correctness of the statistics collected as hereinbefore described by comparing them with the returns of vital statistics made in a few States in compliance with local laws and usages. Subsequent inquiry proved that for one reason or another this could not be done except for a very few years in Minnesota, Michigan, and Massachusetts. In the first-named State returns made to the State Board of Health for the years 1896, 1897, and 1898 show a total of 33 deaths by lightning as against 24 according to the figures of the Weather Bureau. In Massachusetts the State Board of Health returns for 1896 and 1897, the only years for which comparisons could be made, showed a slightly greater number of deaths by lightning than were given by the Weather Bureau. In Michigan the State returns and those of the Weather Bureau agreed very closely.

TABLE I.—*Deaths by lightning in the United States,* 1890–1898.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1890	0	0	2	6	8	87	55	12	0	0	0	0	*120
1891	0	0	0	13	23	73	52	34	9	0	0	0	204
1892	0	0	0	5	27	74	67	54	15	6	1	2	251
1893	0	0	5	19	17	66	73	18	8	2	0	1	209
1894	0	2	6	14	45	96	60	78	29	6	0	0	336
1895	0	0	5	29	66	109	123	78	16	0	0	0	426
1896	0	1	6	26	71	45	89	75	21	6	1	0	341
1897	0	1	11	8	44	107	109	61	14	3	4	0	362
1898	0	0	1	2	44	71	110	86	41	12	0	0	367
Sums	0	4	36	122	345	678	738	496	153	35	6	3	2,496
Mean	.....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	.....	312

* Not used in computing the mean.

These data are not sufficient, of course, to establish the general accuracy of the results obtained by Weather Bureau methods. It is quite probable, however, that the accuracy and completeness of the figures vary for different portions of the country, and, as before stated, that the number of deaths given in the table is under rather than above the true figure.

The number of deaths by lightning that occurred in the several States and Territories during the three years 1896, 1897, and 1898, is shown in Table II. It is not possible to give the distribution by States for earlier years.

When we attempt to analyze the figures in the first column of Table II we are met by a number of difficulties. Evidently the number of deaths by lightning in any community depends largely upon the number of persons exposed to thunderstorm action, and, in a less degree, upon the number of thunderstorms. It has been satisfactorily shown by Flammarion and Lawson, whose reports will be referred to in a subsequent portion of this paper, that danger from lightning stroke is reduced to a minimum in large cities and very thickly populated districts. If, therefore, the relative frequency of fatal lightning strokes be determined by the proportion of deaths therefrom to the total population, those districts in which the urban element largely predominates will show an immunity scarcely in accordance with the facts.

As a first rough approximation to the relative frequency by States, the number of fatal cases per unit of 100,000 agricultural laborers, a class of persons fully exposed to the vicissitudes of thunderstorm action, was calculated. The results for the farming States of the central valleys and the middle west, while consistent in some cases, were not so in others. Thus, for Ohio, the average annual death rate by lightning per unit of 100,000 agricultural laborers was 24; Indiana, 28; Illinois, 11; Iowa, 23; Michigan, 19; Wisconsin, 13. There is no reason known for the apparent immunity of agricultural laborers in Illinois from lightning stroke. In other States, especially those in which stock raising and mining interests predominate, the results were not satisfactory.

The unit of comparison next selected was 1,000,000 persons engaged mainly in outdoor pursuits, classed as follows: Agricultural laborers, apiarists, dairymen, dairywomen, farmers, planters, overseers, fishermen, oystermen, gardeners, florists, nurserymen, vine growers, lumbermen, raftsmen, quarrymen, stock raisers, herders, drovers, wood choppers, and others.

The enumeration of persons engaged in those pursuits was made in 1890 (Eleventh Census, Population of the United States, Part II, Table 79), and, therefore, the absolute values of death rate are a little greater than they would be for the population of the years

1896–98, but for comparative purposes this does not greatly matter. The ratio of fatalities per 1,000,000 persons engaged in outdoor pursuits is shown in the table below, both by States and geographic districts. We have added, for the sake of comparison, the ratio per million of rural population, defining as that element persons living in the country or in cities containing less than 8,000 inhabitants.

The statistics do not extend over a period long enough to enable us to draw definite conclusions as to the relative frequency of deaths by lightning stroke in the several States and Territories, but if we group them by larger geographic divisions having about the same thunderstorm frequency, we obtain what may be considered a first approximation to the true distribution. Such a grouping has been made, the results appearing in Table II.

We may observe in regard to the results shown in this table, first, that in the older and more densely populated districts, New England and the Middle Atlantic States, the proportion of fatal cases is more uniform than might be expected, and, second, that the number of fatal cases is generally large in regions of relatively great thunderstorm frequency, as shown by Plate I.

In the South Atlantic and Gulf States several incongruous results appear. Thus, the ratio of deaths in North Carolina, Georgia, Louisiana, and Alabama would appear at first sight to be considerably below the true figure and out of all proportion to the average number of thunderstorms. This may be due to a failure to report all deaths, particularly those of the colored race.

In Tennessee and the States of the Ohio Valley the figures seem to indicate as great a frequency as was observed in the Middle States, although the frequency of thunderstorms is somewhat greater.

The States of the central Mississippi Valley, except Iowa, show a smaller proportion of deaths than was to be expected.

The districts showing the greatest proportion of fatal cases are the Missouri Valley, the Plains, and the Rocky Mountain and Plateau regions. We should not fail to point out, however, that while the States of Montana, Wyoming, and Colorado contain a relatively small agricultural population, the proportion of fatal cases to the total population is twenty-one in a million, an unusually high rate.

The ratios obtained for Oklahoma and North Dakota were not used in computing the district averages. It is quite probable that the rate of increase in the population of Oklahoma subsequent to the organization of that Territory in 1890, has been considerably greater than in the older neighboring States. In the case of North Dakota, however, there has been, so far as known, no extraordinary increase in population. If we assume that the population has doubled within the last eight or nine years, the ratio of deaths to the total population is still very high, viz, sixteen in a million.

It should be remembered that the correctness of the ratios of the table depends in a measure upon the size of the numbers whence they were derived. In general, the larger the figures the greater is the probability that the corresponding ratios are correct. The smaller the numbers the greater is the possible error in the ratios derived from them.

TABLE II.—*Number of deaths by lightning in the United States during the three years,* 1896, 1897, *and* 1898, *also the ratio of deaths in a million living, classed as follows: Persons engaged in outdoor pursuits, rural population, and total population.*

State and district.	Total population. [1890.]	Total in 3 years.	Rate per million.		
			Outdoor pursuits.	Rural population.	Total population.
(1)	(2)	(3)	(4)	(5)	(6)
New England.					
Maine	661,086	2	8	1	1
New Hampshire	376,530	3	23	4	3
Vermont	332,422	5	30	5	5
Massachusetts	2,238,943	11	45	5	2
Rhode Island	345,506	1	27	5	1
Connecticut	746,258	6	41	6	3
Average		4.7	29	4	2
Middle Atlantic States.					
New York	5,997,853	63	53	9	4
New Jersey	1,444,933	16	73	8	4
Pennsylvania	5,258,014	71	70	8	5
Delaware	168,493	3	54	9	6
Maryland	1,042,390	9	30	5	3
Virginia	1,655,980	35	44	8	7
Average		32.8	54	8	5
South Atlantic States.					
North Carolina	1,617,947	14	12	3	3
South Carolina	1,151,149	46	47	14	13
Georgia	1,837,353	31	25	6	6
Florida	391,422	18	91	17	15
Average		27.2	44	10	9
Gulf States.					
Alabama	1,513,017	35	31	8	8
Mississippi	1,289,600	13	12	3	3
Louisiana	1,118,587	18	18	5	4
Texas	2,235,523	62	48	10	9
Average		30.8	27	6	6
Central Mississippi Valley.					
Arkansas	1,128,179	28	30	7	7
Oklahoma	61,834	8	192	43*	43*
Missouri	2,679,184	43	37	7	5
Iowa	1,911,896	50	52	10	9
Illinois	3,826,351	41	31	6	4
Average		35.0	68	7	6
Upper Mississippi Valley.					
Minnesota	1,301,826	24	41	9	6
Wisconsin	1,686,880	25	35	7	6
Michigan	2,093,889	41	47	8	7
Average		30.0	41	8	6
Upper Missouri Valley and Plains.					
North Dakota	182,719	18	187	33*	33*
South Dakota	328,808	8	39	8	8
Nebraska	1,058,910	24	47	10	8
Kansas	1,427,096	28	37	7	7
Average		19.5	65	8	8

* Not included in averages.

TABLE II.—*Number of deaths by lightning in the United States*—Continued.

State and district.	Total population. [1890.]	Total in 8 years	Rate per million.		
			Outdoor pursuits.	Rural population.	Total population.
(1)	(2)	(3)	(4)	(5)	(6)
Ohio Valley and Tennessee.					
Indiana	2,192,404	72	75	18	11
Ohio	3,672,316	78	64	10	7
Kentucky	1,858,635	36	37	8	6
Tennessee	1,767,518	38	38	8	7
West Virginia	762,794	6	17	3	3
Average	....	46.0	46	8	7
Rocky Mountain and Plateau Region.					
Montana	132,159	11	240	34	28
Wyoming	60,705	6	245	41	33
Colorado	412,198	22	187	28	18
New Mexico	153,593	1	14	2	2
Arizona	59,620	4	191	22	22
Utah	207,905	2	33	5	3
Nevada	45,761	0	0	0	0
Idaho	84,385	0	0	0	0
Average	....	5.8	114	16	13
Pacific Coast.					
California	1,208,130	2	5	1	1
Oregon	313,767	1	7	1	1
Washington	349,390	0	0	0	0
Average	... .	1.0	4	1	1

In comparing the relative frequency of fatal lightning strokes in the United States with that of European countries it is most convenient to consider the ratio of deaths to each million of the total population. The ratio of deaths by lightning in the United States during the nine years, 1890–1898, for which period we may assume the average population to have been, in round numbers, 65,000,000, was 5 persons in a million living. This rate is somewhat larger than generally obtains in Europe, if we except the region of the Austrian Alps and perhaps Prussia. The ratio of deaths by lightning in the provinces of Styria (Steirmark) and Carinthia (Kärnthen) for a nine-year period, is about 10 persons in a million living.[1] According to the earlier statistics for Prussia[2] for the fifteen years 1869–1883 the ratio was 4.4 in a million. A more recent publication gives the average number of persons killed by lightning in Prussia from 1882–1891 as 167.[3] On the basis of a total population of 28.5 millions during this period the ratio would be 6 in a million.

Information respecting the loss of life by lightning in Europe is not so comprehensive as might be expected. We give in the following paragraphs a brief résumé of the more important writings on the subject.

The deaths from lightning in England and Wales from 1852 to 1880, both inclusive, are given by Dr. Robert Lawson, Inspector General of Hospitals, in a paper communicated to the Royal Meteorological Society of London, January 22, 1889. (Quarterly Journal, Royal Met. Soc., Vol. XV, p. 140.) Dr. Lawson calls attention to the fact that deaths from lightning fluctuated considerably in different years; thus in 1863 there were 3 only, in 1864, 6, and in 1869, 7, while in 1852 there were 45, and in 1872, 46. Grouping them by periods it appears that the deaths in the country generally in 1852–1860, were 1.5 in one million persons; in 1861–1870, 0.65; and in 1871–1880, 0.95, the average for the whole period being 0.88, less than one person in a million.

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[1] Mittheilungen des naturw. Vereines für Steirmark. 1897.

[2] Beiträge zur Statistik der Blitzschläge in Deutschland. Hellman. Berlin, 1886.

[3] Die Zunahme der Blitzgefähr und die Einwirkung des Blitzes auf den Menschlichen Korper. Blenck. E. Berlin, 1894.

The ratio of deaths was least in metropolitan and coast districts and greatest in the midland districts.

The published information for France is exceedingly brief. The only statistics we have been able to find are those given by M. Flammarion in Révue Mensuelle d'Astronomie populaire et de Météorologie. M. Flammarion finds that during the period 1835–1859 there were, on an average, 75 deaths annually, and that during the period 1860–1883 this number was increased to 114. The difference is explained on the ground that the statistics for the earlier years were incomplete, and that there were fewer omissions in the second series of years.

He assumes that, on an average, 114 persons are killed annually by lightning in France, or 3 for each million of living persons.

M. Flammarion points out the fact that in twenty years there was not a single death from lightning in the Department of the Seine, the metropolitan district.

Statistics of loss of life by lightning stroke in Belgium have been collected by Messrs. Evrard and Lambotte, directors of telegraph service, but only the years 1884–1889 are available. The number of persons killed during the six years was 74, or an average of 12.3 per annum. Assuming the population of the country to have been 5,800,000 during the above-named period, we have for the annual mortality by lightning a little over 2 persons in a million. The statistics for 1889, which we have drawn from Ciel et Terre, Vol. XII, p. 160, show that of the 18 persons killed 1 was within a building, 11 were without, and 6 were under trees. Forty-three persons were injured during the year, of which 20 were within buildings, 19 without, and 4 were under trees.

In Sweden the average number of persons killed annually by lightning during the period—

1816–1825	was	9.7	in	2.6	million	inhabitants.
1826–1835	was	10.0	in	2.9	"	"
1836–1845	was	8.7	in	3.1	"	"
1846–1855	was	11.8	in	3.4	"	"
1856–1865	was	10.8	in	3.8	"	"
1866–1875	was	13.2	in	4.2	"	"
1876–1883	was	14.2	in	4.6	"	"

The increase in population from 1820 to 1880 was 77 per cent, while the increase in deaths by lightning in the same period was but 46 per cent, thus showing a relative decrease in the number of strokes. In the first period there were 3.7 deaths in a million inhabitants; in the last fifteen years of the record, 1869–1883, there were but 3.0 deaths in a million inhabitants.

In Prussia, as before stated, the ratio of deaths for the period 1869–1883 was 4.4 per unit of one million living persons, but for the ten years 1882–1891 the ratio was 6 in a million. In Baden, 1867–1883, the ratio was less, viz, 3.8. In Bavaria, 1882–1890, on a basis of a total population of 5.5 millions, the ratio was 4.4. In Saxony, 1882–1889, on a basis of a total population of 3.2 millions, the ratio was 5 in a million.

For the great Russian Empire we have been unable to obtain definite statistics. Klossovsky gives the average number of deaths in southwestern Russia for a period of seven years as 11[1]. The extent of territory included within that designation is not known; hence it is not possible to reduce the figures to a comparable basis.

Loss of property by lightning.—We have already seen that it is a difficult matter to obtain accurate returns of loss of life by lightning. In the case of property the difficulties are much greater. It would seem easy enough to deal with all property that is either directly or indirectly insured against loss by lightning; many companies, however, do not differentiate the causes of loss with sufficient minuteness to include loss due to lightning, being satisfied to include such loss under the general caption "loss by fire." In the large number of cases not covered by insurance we can form an approximate estimate of the loss or damage it is true, but we have no assurance that all of the cases of loss which occur come to our notice.

In many States of the middle west a large number of farmers' mutual fire insurance associations have been organized within recent years. These associations insure farm property, including live stock and growing crops, against loss by lightning, hail, and, in some cases, tornado. The farmers' mutuals, as they are called, operate mainly in the States of Illinois, Iowa, Minnesota, Wisconsin, Michigan, Nebraska, Missouri, Indiana, and Ohio, and it is to them we are mainly indebted for the statistics upon which this report is based.

The nature of the information sought to be collected by the Weather Bureau is shown by the following blank:

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[1] Review Meteorologique, Odessa, Vol. III, 1890–1894.

Form No. 4089—Mis.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

LOSS BY LIGHTNING.

Date of storm.................. ...., 189 ; hour of day, ...M.
Where loss occurred, ... Township, ... Co., ...
State ....
On whose premises? ....
Kind of building struck? ....
Of what constructed (wood, brick, or stone)? ....
Kind of roof (shingle, slate, or metal)? ....
If building burned, how much loss? .... $.............. ....
Value of contents burned........ ... . $...............
If struck and not burned, how much damage? .... $........... ....
Was it provided with lightning rods? ....
If so, what metal was used? ....
What were the dimensions of buildings? Height, ...; length,...... ....
width, ...
How many points on the roof? ....

LIVE STOCK KILLED IN THE FIELD.

Kind of stock, ...; number,........................
Amount of loss, ...$........... .. . ..
Was the stock near a wire fence? ... .
If near fence were ground wires used? ....

Please add details as to character of soil where lightning stroke occurred, whether moist or dry, whether upland or lowland, and whether timber or trees were near. Note special features of the storm, its direction of movement, etc.

(Name).. .. ..

(Post Office address)................................. ....

To be filled up and returned to Director Climate and Crop Service, Weather Bureau............

During the calendar year 1898 reports were received of 1,866 cases of buildings being damaged or destroyed by lightning, nineteen of which, however, were destroyed by reason of being exposed to other buildings that were set on fire by lightning stroke. The loss to buildings and their contents was $1,441,880. Column two of the table below shows the number of buildings damaged or destroyed in each State and Territory; columns three to six show the kind of building damaged or destroyed; columns seven to ten the character of the roof; columns eleven to fourteen whether or not the buildings were equipped with lightning rods; and, finally, columns fourteen to sixteen show the number of known and unknown cases of injury or destruction and the amount of loss in the known cases.

The average loss was $1,276. If we omit, however, six isolated cases of very heavy loss, aggregating $648,000, the average loss would be reduced to $700, an amount more in consonance with the real figures, it is true, but yet seemingly too high.

TABLE III.—*Buildings struck and damaged by lightning in the United States in* 1898.

States.	Total number.*	Kind.				Character of roof.				Rods.			Loss.		
		Barns, sheds, warehouses, etc.	Churches and schools.	Dwellings, stores, and office buildings.	All others.	Wood.	Slate.	Metal.	Unknown.	Yes.	No.	Unknown.	Known cases of.	Unknown cases of.	Amount on buildings and contents.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Alabama	20	5	2	11	2	15			5	1	15	4	14	6	$806 00
Arizona	1		1						1			1		1	
Arkansas															
California															
Colorado	25	8		16	1	20		4	1		25		23	2	2,382 00
Connecticut	52	24	3	25		2	2		48	1		51	7	45	8,750 00
Delaware	7	1	2	4		3			4	1	3	3	3	4	505 00
District of Columbia	2	2							2			2	1	1	1.000 00
Florida	3			3		2			1		1	2	1	2	3 00
Georgia	10	4		6		8			2		10		5	5	400 00
Idaho															
Illinois	171	95	10	63	3	120	2	3	44	7	76	86	128	43	348,097 00
Indiana	82	43	4	33	2	37	1	1	43	2	30	50	41	41	102,768 00
Iowa	58	42		16		33	1		23	2	26	29	37	21	17,861 00
Kansas	46	26	1	17	2	28		1	17		24	22	29	17	42,831 00
Kentucky	10	3	2	5		7		2	1	1	6	3	9	1	1,184 00
Louisiana	5			5		1			4		1	4	3	2	225 00
Maine	15	5		9	1				15			15	1	14	3,000 00
Maryland	22	11		9	2	15	1		6	4	13	5	16	6	10,785 00
Massachusetts	117	36	8	54	19	15			98	1	6	106	32	85	55,699 00
Michigan	77	52	1	24		46	2	1	25		42	32	56	21	30,840 00
Minnesota	64	32	4	27	1	30		1	33	1	27	36	45	19	31,258 00
Mississippi	7	2		4	1	5			2		4	3	5	2	570 00
Missouri	58	28	4	25	1	33		2	23	1	36	21	41	17	10,628 00
Montana	6	1		5		4	1		1		5	1	2	4	91 00
Nebraska	28	9	3	15	1	18		1	9	2	17	9	17	11	10,918 00
Nevada															

New Hampshire	18	5	2	11	....	5	....	....	18	....	5	13	10	8	13,650 00
New Jersey	105	48	9	47	1	10	7	....	88	1	9	95	28	77	36,646 00
New Mexico	1	1	....	....	....	....	....	....	1	....	....	1	1	....	5,000 00
New York	395	256	17	109	18	249	8	8	121	5	243	138	231	114	439,882 00
North Carolina	41	18	1	17	5	23	....	8	15	8	18	20	26	15	10,015 00
North Dakota	12	7	8	2	....	11	....	....	1	....	8	4	11	1	1,745 00
Ohio	84	38	5	37	4	38	7	1	48	....	38	46	55	29	32,849 00
Oklahoma and Indian Territory	5	2	....	8	....	2	....	....	8	....	2	3	4	1	280 00
Oregon	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pennsylvania	73	29	2	35	6	16	2	1	53	....	16	56	26	46	82,004 00
Rhode Island	5	1	2	1	1	....	....	....	5	....	....	5	1	4	10,000 00
South Carolina	34	17	1	16	....	24	1	2	7	....	23	11	23	11	17,006 00
South Dakota	57	28	4	25	....	47	....	1	9	....	40	17	44	13	8,982 00
Tennessee	4	1	....	2	1	2	....	....	2	1	0	3	2	2	725 00
Texas	14	4	1	8	1	9	....	1	4	2	8	4	9	5	1,615 00
Utah	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Vermont	7	3	....	4	....	1	....	....	6	....	....	7	1	6	2,000 00
Virginia	21	9	2	9	1	8	1	....	12	....	7	14	9	12	11,705 00
Washington	2	1	....	....	1	....	....	....	2	....	....	2	....	2	....
West Virginia	27	17	....	10	....	17	3	1	6	3	19	5	17	10	14,847 00
Wisconsin	75	52	1	22	....	50	....	....	16	1	52	22	66	9	23,500 00
Wyoming	1	....	....	1	....	....	....	....	1	....	....	1	....	1	....
Totals	1,866	966	95	735	70	958	39	34	816	40	855	952	1,130	736	1,441,880 00

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*The total number of strokes was 1,847; the figures given in this column include buildings set on fire by exposure to fires caused by lightning.

TABLE IV.—*Number of fires in the United States by lightning, insured buildings only.*

[From Chronicle Fire Tables.]

	Number of fires caused by lightning.								Kind of buildings.					Total.	Insurance in force per square mile.
	1890.	1891.	1892.	1893.	1894.	1895.	1896	1897.	Barns.	Dwellings.	Churches.	Factories.	All other fires.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Alabama	3	4		8	1	6	5	9	14	20	1	1		36	$587 00
Arizona								2	1				1	2	
Arkansas	3	2		1			5		5	3	3			11	13 00
California	1			1			2	1	2	3				5	2,879 00
Colorado	3						5	10	7	10	1			18	46 00
Connecticut	32	17	45	23	14	37	58	19	129	95	10	8	3	245	289,866 00
Delaware	9	7	6	3	3	6	6	5	34	5		1	5	45	14,067 00
District of Columbia	0			1	2	1	2		2	3	1			6	785,286 00
Florida	2	2	3	7	3	7	3	6	8	24	1			33	
Georgia	11	5	2	13	10	6	20	19	42	36	4	1	3	86	847 00
Idaho							1			1				1	
Illinois	25	30	25	38	58	66	104	72	236	139	22	6	15	418	8,668 00
Indiana	42	41	58	48	46	26	144	96	347	98	32	10	14	501	1,239 00
Iowa	27	21	12	14	37	45	67	82	211	51	20	9	14	305	4,752 00
Kansas	1	5	3	7	10	14	40	22	57	36	5	3	1	102	97 00
Kentucky	16	7	7	9	4	5	28	23	55	34	6	2	2	99	1,961 00
Louisiana	9	4	5	3	4	1	5	6	5	27	4		1	37	2,817 00
Maine	19	29	40	20	50	22	32	25	157	73	5	1	1	237	340 00
Maryland	8	14	19	16	33	22	41	40	143	41	1	2	6	193	16,105 00
Massachusetts	25	24	40	35	40	54	42	43	144	123	20	14	2	303	123,296 00
Michigan	31	33	86	55	69	35	162	74	396	114	21	7	7	545	3,918 00
Minnesota	15	19	18	6	13	21	46	34	89	57	5	5	16	172	1,848 00
Mississippi	2	1	2	3	2	2	2	6	8	8	2	1	1	20	108 00
Missouri	17	9	7	32	40	9	51	47	117	72	9	10	4	212	1,979 00
Montana	0		0	0	0	0	3	2	4	1				5	
Nebraska	6	6	3	17	10	15	37	16	63	34	8	3	2	110	677 00
Nevada	0	0	0		0		2			2				2	
New Hampshire	9	4	4	9	13	6	11	20	50	23	2	1		76	20,029 00
New Jersey	34	19	46	24	39	54	97	38	233	101	11	3	3	351	44,846 00
New York	88	41	171	97	95	154	175	191	733	223	25	21	10	1,012	106 494 00

North Carolina	9	3	7	6	8	6	13	7	31	18	5	5	....	59	538 00
North Dakota	1	1	2	2	....	1	6	6	17	1	....	1	....	19	5 00
Ohio	60	36	43	36	23	15	134	238	448	100	23	13	6	590	9,764 00
Oklahoma and Indian Territory	....	....	0	....	3	2	....	3	1	6	....	....	1	8	....
Oregon	....	2	0	....	....	....	1	....	2	1	....	....	....	3	231 00
Pennsylvania	75	39	119	32	104	93	183	214	613	187	34	12	12	858	51,699 00
Rhode Island	4	1	6	13	9	7	19	15	23	43	1	3	4	74	36,861 00
South Carolina	2	4	0	1	6	3	9	4	15	12	2	....	....	39	145 00
South Dakota	....	5	7	....	6	9	17	12	31	18	1	2	4	56	238 00
Tennessee	1	....	1	8	6	8	28	16	36	22	4	1	....	63	7,657 00
Texas	5	9	11	15	16	10	13	17	49	39	5	....	3	96	33 00
Utah	....	....	2	....	....	....	....	3	3	2	....	....	....	5	....
Vermont	....	....	5	6	7	10	16	19	45	15	2	....	1	63	5,580 00
Virginia	5	....	9	12	9	4	16	19	43	22	4	....	5	74	1,566 00
Washington	....	2	0	....	1	1	1	3	2	3	2	....	1	8	30 00
West Virginia	3	1	4	2	3	4	14	18	34	9	1	....	....	44	633 00
Wisconsin	22	10	21	42	49	52	73	49	205	79	24	7	3	318	5,996 00
Wyoming	....	....	....	....	1	....	....	2	1	1	1	....	....	3	....
Total	625	457	839	660	852	839	1.788	1,548	4,891	2,035	328	153	151	7,558	....

TABLE IV.—*Number of fires in the United States by lightning, insured buildings only.*

[From Chronicle Fire Tables.]

States.	Number of fires caused by lightning.								Kind of buildings.					Total.	Insurance in force per square mile.
	1890.	1891.	1892.	1893.	1894.	1895.	1896	1897.	Barns.	Dwellings.	Churches.	Factories.	All other fires.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Alabama	3	4	......	8	1	6	5	9	14	20	1	1	......	36	$587 00
Arizona	......	......	......	......	......	......	......	2	1	......	......	......	1	2	......
Arkansas	3	2	......	1	......	......	5	......	5	3	3	......	......	11	13 00
California	1	......	......	1	......	......	2	1	2	3	......	......	......	5	2,879 00
Colorado	3	......	......	......	......	......	5	10	7	10	1	......	......	18	46 00
Connecticut	32	17	45	23	14	37	58	19	129	95	10	8	3	245	289,366 00
Delaware	9	7	6	3	3	6	6	5	34	5	......	1	5	45	14,067 00
District of Columbia	0	......	......	1	2	1	2	......	2	3	1	......	......	6	785,286 00
Florida	2	2	3	7	3	7	3	6	8	24	1	......	......	33	......
Georgia	11	5	2	13	10	6	20	19	42	36	4	1	3	86	847 00
Idaho	......	......	......	......	......	......	1	......	......	1	......	......	......	1	......
Illinois	25	30	25	38	58	66	104	72	236	139	22	6	15	418	8,683 00
Indiana	42	41	58	48	46	26	144	96	347	98	32	10	14	501	1,239 00
Iowa	27	21	12	14	37	45	67	82	211	51	20	9	14	305	4,752 00
Kansas	1	5	3	7	10	14	40	22	57	36	5	3	1	102	97 00
Kentucky	16	7	7	9	4	5	28	23	55	34	6	2	2	99	1,961 00
Louisiana	9	4	5	3	4	1	5	6	5	27	4	......	1	37	2,817 00
Maine	19	29	40	20	50	23	32	25	157	73	5	1	1	237	340 00
Maryland	8	14	19	16	33	22	41	40	143	41	1	2	6	193	16,105 00
Massachusetts	25	24	40	35	40	54	42	43	144	123	20	14	2	303	123,296 00
Michigan	31	33	86	55	69	35	162	74	396	114	21	7	7	545	3,918 00
Minnesota	15	19	18	6	13	21	46	34	89	57	5	5	16	172	1,848 00
Mississippi	2	1	2	3	2	2	2	6	8	8	2	1	1	20	108 00
Missouri	17	9	7	32	40	9	51	47	117	72	9	10	4	212	1,979 00
Montana	0	......	0	0	0	0	3	2	4	1	......	......	......	5	......
Nebraska	6	6	3	17	10	15	37	16	63	34	8	3	2	110	677 00
Nevada	0	0	0	......	0	......	2	......	......	2	......	......	......	2	......
New Hampshire	9	4	4	9	13	6	11	20	50	23	2	1	......	76	20,029 00
New Jersey	34	19	46	24	39	54	97	38	233	101	11	3	3	351	44,846 00
New York	88	41	171	97	95	154	175	191	733	228	25	21	10	1,012	108 494 00

North Carolina	9	8	7	6	8	6	18	7	31	18	5	5	....	59	538 00
North Dakota	1	1	2	2	....	1	6	6	17	1	....	1	....	19	5 00
Ohio	60	36	43	86	28	15	184	238	448	100	23	18	6	390	9,764 00
Oklahoma and Indian Territory	....	....	0	....	8	2	....	3	1	6	....	....	1	8	....
Oregon	....	2	0	....	....	....	1	....	2	1	....	....	....	8	231 00
Pennsylvania	75	89	119	82	104	98	182	214	613	187	34	12	12	858	51,699 00
Rhode Island	4	1	6	18	9	7	19	15	23	48	1	3	4	74	36,861 00
South Carolina	2	4	0	1	6	3	9	4	15	12	2	....	....	29	145 00
South Dakota	....	5	7	....	6	9	17	12	31	18	1	2	4	56	238 00
Tennessee	1	....	1	3	6	8	28	16	36	22	4	1	....	68	7,657 00
Texas	5	9	11	15	16	10	18	17	49	39	5	....	3	96	38 00
Utah	....	....	2	....	....	....	....	8	3	2	....	....	....	5	....
Vermont	....	....	5	6	7	10	16	19	45	15	2	....	1	63	5,520 00
Virginia	5	....	9	12	9	4	16	19	43	22	4	....	5	74	1,566 00
Washington	....	2	0	....	1	1	1	3	2	8	2	....	1	8	30 00
West Virginia	3	1	4	2	3	4	14	18	34	9	1	....	....	44	638 00
Wisconsin	23	10	21	42	49	52	73	49	206	79	24	7	3	318	5,996 00
Wyoming	....	....	....	....	1	....	....	2	1	1	1	....	....	3	....
Total	625	457	839	660	852	839	1.788	1,548	4,891	2,035	828	153	151	7,558	....

The average amount paid by insurance associations of Michigan on 4,612 claims for indemnification of loss by lightning was only $111. We should remember, however, that the amount of the average loss in the different sections of the country will vary according to the character of the buildings and improvements. Thus, in Massachusetts, according to Table III, there were thirty-two cases of buildings struck by lightning in 1898, causing damage to the amount of $55,698, or an average of $1,740 per building. On the other hand, forty-four cases of damage to buildings in South Dakota gave an average loss of but $203 per building.

The great property loss in the States of Illinois, New York, Pennsylvania, Indiana, and Minnesota, shown by Table III, is partly due to single cases of heavy loss. Thus, in Illinois the total destruction of a brewery set on fire by lightning involved a loss of $300,000. In the State of New York there was a single loss of $150,000 and a large number of losses exceeding $2,000 each.

The total property loss during the year due to lightning, on the assumption that an average loss of $700 was maintained in the 736 unknown cases, would be about $2,000,000. It is reasonable to suppose, however, that the loss in a great majority of the unkown cases was trifling, and that the total loss in the 1,866 cases was not much over $1,500,000.

The figures in column 2, Table III, showing the number of damaging lightning strokes in the several States and Territories are incomplete in a number of cases. No returns, whatever, were received from Arkansas, a State in which the damage by lightning stroke is believed to be rather above than below the average.

The fidelity with which the figures in column 2 represent the actual number of damaging lightning strokes in any State must depend, among other things, upon the proportion of insured to uninsured buildings, the density of inhabited buildings, and the frequency of thunderstorms. The returns from Iowa, Illinois, Minnesota, Wisconsin, Michigan, Indiana, Nebraska, Ohio, New York, and Missouri, are probably more accurate than those from other States and Territories. If present conditions as to collecting statistics remain unchanged for a term of years it will be possible to detect any considerable increase or diminution in the number of damaging lightning strokes, and thus satisfy one of the objects of this inquiry. It will not be possible, however, to determine with reasonable approach to accuracy the regions of greatest danger from lightning. Such a desideratum can not be accomplished until the number of buildings per unit area and the ratio of insured to uninsured are better known than at present.

Table IV shows the number of fires by lightning and the money value of property destroyed during the period 1890–1897 as reported in the Chronicle Fire Tables. (The Chronicle Company, Limited, New York.)

Loss by lightning in 1890	$ 1,618,539 00
1891	1,487,322 00
1892	3,251,494 00
1893	1,843,872 00
1894	2,507,061 00
1895	1,839,786 00
1896	2,936,985 00
1897	2,187,710 00
Total in eight years	$17,672,772 00

We see in Table IV the need of information relative to the proportion of insured to uninsured buildings in the various sections of the country, and this is our reason for adding column 16 to the table as originally prepared. The figures in that column show the total fire risks in force per square mile in each State and Territory on December 31, 1889, (Eleventh Census, Report on Insurance Business, Part I, p. 1004). The small number of fires from lightning in a number of States wherein the frequency of thunderstorms is above the average for the whole country is explained by the relatively small number of insured buildings in those States.

LIVE STOCK IN THE FIELDS KILLED BY LIGHTNING.

Table V shows the number of cattle, horses, mules, and other domestic animals that were killed by lightning in the fields during 1898. The money value of the stock so killed, and the number of lightning strokes are shown in columns 7 and 8, respectively. In this table, more than in any of those which have preceded it, the completeness of the statistics is dependent upon the number and distribution of farmers' mutual insurance agents and adjusters. As we have already remarked, these associations are most numerous in Iowa, Illinois, Minnesota, Wisconsin, Michigan, Indiana, Nebraska, New York, Ohio, and Missouri, for which States the returns are generally more complete than for others, with the exception of Colorado and South Dakota. Both of the last-named States come well within the area of frequent thunderstorm action, and the fatalities from lightning appear to have been faithfully reported. Unfortunately we were unable to secure returns from Wyoming and New Mexico, in both of which regions the conditions are much similar to those which obtain in Colorado.

The remarks made on a previous page regarding the lack of information as to the proportion of insured to uninsured buildings apply with even greater force to live stock. It is quite evident from an examination of the figures in the table that we can not draw any conclusions as to the comparative danger from lightning in different parts of the country.

The total number of damaging strokes that fell upon live stock in the field in the whole country was 700, or 27 per cent of the whole number of damaging strokes observed. While this percentage generally holds good there is one notable exception, viz, in Iowa, where 73 per cent of the total number of damaging strokes fell upon live stock. The reason for the reversal of the general rule in that State is not known. We suspect, however, that it is partly due to the completeness of the record, the cases of damaging lightning stroke upon live stock in that State apparently having been reported with great faithfulness. The Director of the Iowa Weather and Crop Service, commenting upon the loss of live stock by lightning during the past year, says in his September, 1898, Monthly Review:

> These reports show the interesting fact that of the 266 head of live stock killed by lightning, 118 were found in close contact with wire fences; and also that these wire fences were not provided with ground wires. That is to say, over 44 per cent of the losses of live stock may have been caused by contact with wires charged with electric force.
>
> Unquestionably wire fences, as now constructed, serve as death traps to live stock; causing a vast amount of loss every year. And it is also quite evident that a considerable percentage of danger may be avoided by the use of ground wires at frequent intervals, in the construction of wire fences. In some of the reports it was stated that there were evidences that the lightning struck the fence at a considerable distance from the point where the stock was killed.

The wire fence has come into extensive use in the west and southwest and is destined to come into far greater use in the future. The lesson taught by the statistics collected in Iowa and other States is that precautions should always be taken to minimize the probable loss by lightning in all cases where stock is exposed to wire fences during thunderstorms. The use of ground wires, as suggested above, is calculated to lessen the danger from lightning. The subject should receive immediate attention. Nearly one-third of all the cases of damaging lightning strokes in the fields occurred in the immediate vicinity of wire fences.

The returns from California and Colorado afford two cases of very heavy mortality in as many flocks of sheep. In the first case, lightning struck a tall pine tree, under which a flock of nearly 200 sheep were huddled in the manner characteristic of that animal. The flash was quite severe. The two herders, who were a short distance away, being rendered unconscious for a few moments. Fifty-two of the sheep were killed outright, and others were stunned but not seriously injured. The accident occurred at Poison Lake, near Butte Creek, Lassen County, California. The second accident occurred on the farm of Mr. David Laybourn, near Cope, Colorado, 91 sheep being killed by a single stroke. The details are at present lacking.

Owing to the widely varying conditions which obtain in different sections of the country the statistics are worthless for comparative purposes. It is to be hoped, however, that their publication will awaken a lively interest in the matter, and greatly increase the number and completeness of the reports for the present year.

TABLE V.—*Live stock in the fields killed by lightning during* 1898.

States.	Cattle.	Horses.	Mules.	Pigs.	Sheep.	Value.	No. of strokes.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Alabama	....	....	1	....	....	$35	1
Arizona	9	....	....	....	....	201	4
Arkansas	....	....	2	....	....	100	1
California	....	....	....	....	52	104	1
Colorado	54	19	1	....	91	2,595	34
Connecticut	7	....	....	....	....	175	3
Delaware	....	....	....	3	....	30	1
District of Columbia	....	....	....	....	....	....	....
Florida	....	....	....	....	....	....	....
Georgia	3	3	2	....	....	490	6
Idaho	....	....	....	....	....	....	....
Illinois	164	33	....	44	....	6,733	93
Indiana	40	8	....	4	8	1,541	17
Iowa	162	40	1	7	32	6,897	153
Kansas	67	12	....	....	....	1,418	28
Kentucky	7	....	1	....	....	325	3
Louisiana	....	....	1	....	....	70	1
Maine	....	....	....	....	....	....	....
Maryland	5	3	....	....	....	470	6
Massachusetts	2	2	....	....	....	100	2
Michigan	22	15	....	9	77	1,695	34
Minnesota	18	20	....	....	....	1,717	21
Mississippi	....	....	1	....	....	150	1
Missouri	74	15	2	1	....	3,188	37
Montana	3	1	....	....	....	235	3
Nebraska	36	26	1	....	....	2,447	29
Nevada	....	....	....	....	....	....	....
New Hampshire	2	....	....	....	....	50	1
New Jersey	18	1	....	3	....	575	12
New Mexico	....	....	....	....	....	....	....
New York	74	17	....	10	55	3,587	41
North Carolina	7	4	2	10	....	606	8
North Dakota	7	6	....	1	....	620	8
Ohio	21	18	1	5	28	1,894	25
Oklahoma and Indian Territory	10	....	....	....	....	280	1
Oregon	....	....	....	....	....	....	....
Pennsylvania	2	8	1	....	....	1,465	7
Rhode Island	....	....	....	....	....	....	....
South Carolina	5	5	8	10	....	1,045	18
South Dakota	26	23	....	1	8	2,086	25
Tennessee	....	....	....	....	....	....	....
Texas	2	3	5	....	....	480	4
Utah	....	....	....	....	....	....	....
Vermont	....	....	....	....	....	....	....
Virginia	8	3	....	4	....	480	7
Washington	....	1	....	....	....	60	1
West Virginia	3	1	....	....	6	228	2
Wisconsin	106	19	....	4	69	4,205	71
Wyoming	....	....	....	....	....	....	....
Totals	964	306	30	116	426	48,257	710

THE CHARACTER OF THE SOIL.

In the great majority of reports no mention was made as regards the character of the soil at points struck by lightning, perhaps for a lack of information on soil nomenclature.

In very general terms we may say that all soils consist of more or less finely powdered and decomposed rock, sand, clay and vegetable matter, changed to a greater or less extent toward the condition of vegetable mold or humus. The relative proportions of these three principal constituents determine, in a general way, the classification of soils according to their nature. Accordingly we have those in which sand predominates, known as light or sandy soils; those in which clay is the principal element, known as heavy or clayey soils, and, finally, soils containing at least 5 per cent of humus, known as vegetable soils. These latter may be further subdivided into clayey humus, loamy humus, and sandy humus.

In addition to the above general classification we should include what is commonly known in the middle west as *prairie* soil, viz, a soil of very fine, close texture and of great fertility. This soil is found in Indiana, Illinois, Iowa, Kansas, Nebraska, and other States. It is a drift soil or diluvial deposit, and of a different formation from the alluvial soil of the river bottoms. There is also the fine clay-like soil "loess," found principally along the Missouri and Mississippi river bottoms.

Practical men are apt to classify soils in various ways, as for example, according to their weight or agricultural value. In an investigation of this character a very broad and general classification answers best. The classification we would recommend is as follows: sandy soils, clayey soils, and loamy soils (the latter such as have their grains intermediate between those of the sandy and heavy clayey types), prairie soils, swamp and loess soils. The term "prairie" should be applied to upland soils to distinguish them from the alluvial soils of river bottoms in the same neighborhood.

The order of frequency of lightning stroke on the various soils in percentages, deduced from 380 reports is as follows: loam, 26 per cent; sand, 24 per cent, clay, 19 per cent; prairie, 19 per cent; scattering, 12 per cent.

We fail to see wherein the character of the soil should have a marked influence upon the frequency of lightning stroke. We may observe, however, that the order of frequency as given above, is about the same as found by Dr. G. Hellmann for North Germany, although the percentage of strokes upon loam in the last-named country was much greater than in this country. The figures given by Dr. Hellman are as follows:

> If we call the liability (to lightning stroke) for chalk formation 1, then it is 2 for marl, 7 for clay, 9 for sand, and 22 for loam. (Beiträge zur Statistik der Blitzschläge in Deutschland, Berlin, 1886).

KIND OF TREES STRUCK BY LIGHTNING.

Aside from the interest that belongs to this question from a scientific point of view, there is a practical consideration of much importance, viz, if certain trees are found to be good lightning conductors, such trees only should be planted around the home and outbuildings as a natural and inexpensive form of lightning rod, and these trees should be avoided as a temporary refuge in time of thunderstorm.

As long ago as 1787 Mr. Hugh Maxwell, of Massachusetts, called attention to the fact that lightning often strikes the elm, the chestnut, every species of the oak and pine, but rarely, if ever, the beech, birch or the maple. (Memoirs American Academy of Arts and Sciences, Vol. II, p. 143.)

Professor Dennison Olmstead of Yale College remarked in 1850 in a paper read before the American Association for the Advancement of Science, that there is a popular impression in the southern part of the United States that the pine is more apt to be struck by lightning than other trees. This impression, he further observed, could not be due to the fact that in certain districts pine forests are the most extensive of any, since even when mixed with other trees of the forest the pine seems most frequently assailed, notwithstanding its resinous character which would lead us to expect for it an exemption from attacks of lightning. Professor Elias Loomis, commenting upon Professor Olmstead's paper, stated that in Ohio there is a common belief that the beech is never struck, although he had knowledge of one such being struck.

A correspondent of the St. Louis Globe-Democrat (1898) contributes the following in regard to the immunity of the beech from lightning:

> In your issue of the 11th instant, page 42, under the heading "News of Electricity," the question is asked: What tree is safest for shelter in a thunderstorm? The answer is the beech. It is not the first time this tree has been mentioned as a protector from lightning in your paper. Some years ago a contributor recommended the planting of beech trees around the farm to protect man and beast from lightning, with the statement that lightning had never been known to strike one.
>
> I will give you the result of my investigation on the subject. The woodland on the home of my youth in the State of Florida was beech hummock. At that time (from 1850 to 1855) we subscribed for the Southern Cultivator. An article in that paper recommended the planting of beeches about the farm as a protection from lightning stating they were never struck by it. After reading the article I went at once to the hummock in search of a beech struck by it. I soon found two, not more than 20 feet apart, struck apparently by the same discharge, and only a short time prior to the discovery as the fresh mark on the bark indicated. But instead of ripping off a strip of bark and wood 2 or 3 inches wide, as it would have done on an oak or a pine, it simply ploughed a narrow groove through the bark about the eighth of an inch wide. It looked like the channel cut with a woodcarver's paring tool. I watched them afterward to see if they would wither and die from the shock, like other kinds of timber, but they did not. The rents soon began to heal by new bark growing over them, and in a few months formed a ridge or vein along the side of the stroke about 1¼ inch wide and protruding above the level of the trunk about half its width ⅝ of an inch. Such veins on beeches always result from a stroke of lightning. In regard to trees rent and torn asunder when the bark is dry and only scorched when it is wet, it is probable the bark of the beech, being so smooth, will, when covered with a film of water in a rain, conduct electrical discharges to the ground without injury to the tree.

In Germany, as in perhaps no other country, matters affecting the welfare and preservation of the forest receive very great consideration. We are, therefore, not surprised that the comprehensive plan of observation and experiment in German forests, instituted by the government in 1875, should yield among other things a striking confirmation of the opinion expressed by Hugh Maxwell, as before stated. The observations to which we particularly refer are those conducted by the overseers of nine forestry stations scattered throughout an area of about 45,000 acres in the dukedom of Lippe.

The results of these observations have already been published, but we doubt if they are familiar or generally accessible to American readers, and we, therefore, insert them here. We should first observe that the percentage of the various species of trees of which the forest is composed is, approximately, as follows: beech, 70 per cent; oak, 11; pines, 13; firs, 6.

Number of trees struck by lightning.

Variety.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1890.	Total.
Oak	17	45	11	9	4	40	27	6	159
Beech	7	4	1	1	....	6	2	....	21
Pine	6	3	1	....	....	4	3	3	20
Fir*	9	11	....	....	....	23	11	5	59
Birch	....	1	....	....	....	2	1	....	4
Larch	....	2	....	....	....	1	4	.....	7
Ash	1	1	....	....	....	2	1	....	5

* Pinus Silvestris.

If the liability of the beech to lightning stroke be considered as 1, we obtain for the remaining principal varieties the values shown in the following table:

Liability to lightning strokes of the oak, pine, and fir. (*Beech* = 1.)

Variety.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1890.
Beech	1.0	1.0	1.0	1.0	....	1.0	1.0	†
Oak	15.5	71.6	70.0	57.3	*	42.4	85.9	....
Pine	4.6	4.0	5.4	......	....	3.6	8.1	....
Fir	15.0	32.1	....	....	....	44.7	64.2	....

* Only oaks struck. † No beeches struck.

The above figures seem to show that the liability of the oak is always many times greater than that of the beech and that it varies considerably from year to year.

A very elaborate and rather ingenious investigation of the underlying causes of the seeming preference of lightning for certain trees was made by Mr. Dimitrie Jonesco, in Stuttgart, 1890, 1891, and 1892.[1] Jonesco laid aside, as having little or no influence, such physical conditions as the character of the soil, whether dry or moist, and the depth to which the roots of trees penetrate. He began his experiments by determinating the conductivity of the wood of different species of trees, a line of research previously followed by Du Moncel,[1] who failed, however, to reach definite conclusions.

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[1] Ursachen der Blitzschläge in Bäume. Stuttgart, 1892.

Experiments with oak and beech indicated that the former was a much better conductor than the latter, thus confirming observations in the forests of Lippe, if we assume that conductivity plays the most important part. The cause of the better conductivity of one species of trees as compared with another was next sought, and as a first experiment it was looked for in the moisture contents of fresh wood—wood fresh cut from living trees—of different species. The percentage of moisture according to Schubler and Hartig is: for black poplar 51.8 per cent, beech 39.7, and oak 35.4. It was found, however, that the conductivity of wood was independent of its moisture contents.

Extending the range of the experiments so as to include a microscopic examination of the different woods, Jonesco found that the fresh wood of trees, rich in fatty materials, (Fettbäume), was in all cases a poor conductor of electricity, and the greater the proportion of fatty materials in the wood the poorer the conductor. The fresh wood of trees rich in starchy materials (Starkebäume) but poor in fatty materials, on the other hand, conducted electricity very well, although no important differences were noted for the various kinds of wood.

The distribution of fatty materials and starch in the wood of trees has been investigated by Fisher[2] and Suroz,[3] who have shown that the quantity of oil and starch varies with the time of year. It is possible to distinguish, therefore, (1) trees whose wood is always rich in fatty material, for example, walnut and beech; (2) trees whose wood in summer is deficient in fatty materials, as the pine, and finally (3) trees whose fatty contents are intermediate between those of classes 1 and 2, their fatty contents in winter falling below those of No. 1, and in summer rising considerably above those of class No. 2. Trees rich in fatty materials in summer appear to possess a high degree of immunity from lightning stroke, those richest in oil having the greatest immunity. On the other hand, trees deficient in fatty materials during the thunderstorm season, as also the trees rich in starch, are preferred by the lightning. The fact that lightning in winter thunderstorms is rarely observed to strike trees is explained on the ground that the wood of most of our cultivated trees is rich in oil during winter.

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[1] Recherches sur la conductibilitée électrique des corps médiocrement conducteurs et les phénomènes qui l'accompagnent. (Annales de chimie et de physique. 5 serie. T. X. S. 471 ff.)

[2] Beitrage zur Physiologie der Holzgewachse. (Pringsheim's Jahrb. für wissensch. Botanik. Bd. VII.)

[3] Öl als Reservestoff der Bäume. (VIII Kongress russicher Naturforscher und Ärtzte; Botanik s. 24–28; russisch.)

As a check upon his work Jonesco took the wood of typical trees rich in fatty materials, beech and walnut, and found, after depriving them of their oil by means of ether, that the conductivity was increased and became practically the same as that of typical trees rich in starchy material (Starkebäume).

In general, the effect of lightning stroke on trees is to plow one or more furrows down the side as shown in Plate II. The tree in this illustration is a black walnut (*Juglans nigra, L.*) a little over 2 feet in diameter, situated on the edge of a forest and about 100 paces from a barn, which together with a dwelling house, the latter surrounded by locust trees (*G. triacanthos, L.*) stands on the knob of a slight eminence. The tree was struck in January, 1899. A much more destructive effect is shown in Plate III. The tree in this case is an oak (*Q. rubra, L.*) 16 inches in diameter and about 50 feet high. It was struck in the summer of 1898, and the photograph from which the illustration was made was taken in March, 1899. The trunk of the tree lies on the right side of the stump as it fell. It is not very clearly outlined in the photograph on account of the dead leaves that still cling to the branches. The remarkable feature in this case is the fact that there is not a single vestige of the effect of the lightning stroke on the prostrate trunk above the point of fracture or splintering. It would seem as if the entire force of the discharge was felt only at the point of fracture. The ground at the root of the tree was not disturbed, and save for a slight crack, the stump is intact at the surface of the ground. Another, and somewhat similar case of complete fracture of the trunk of a tree by lightning, was observed in the same neighborhood. In the latter case there was less splintering, probably owing to the toughness of the wood, red cedar, (*J. Virginiana L.*) and the stump showed no injury below the point of fracture. Unfortunately, the top of this tree had been cut up for fuel and carried away before we could examine it. The features above described are not new, a correspondent of Symons's Monthly Magazine, Vol. VII, p. 184, having described somewhat similar ones in 1872.

The suggestion that the effects as above described were caused by horizontal strokes is scarcely admissible. While photographs of lightning show that occasionally a discharge takes place in a horizontal plane it is not seen how such a discharge could strike a single tree in a relatively dense forest without injuring others in its path.

The behavior of lightning in the matter of striking terrestrial objects presents many, at present, inexplicable features. That there is some process of selection whereby one species of tree is preferred to another seems to be an established fact, but the reason for such preference does not seem to be definitely known.

It is difficult to conceive that the difference in the conductivity of one species of tree as compared with another, or in the same species at different seasons, is great enough to have a marked influence upon an electrical discharge from cloud to earth or *vice versa*.

We have noticed, and our observation has been confirmed by the experience of others, that in some localities lightning seems to exercise a decided preference for small apparently isolated areas which thus acquire a local reputation as being dangerous resorts in time of thunderstorm. Such local danger spots do not possess, so far as our observation goes, any common characteristic, whether we consider the character of the soil or the topographic features; although they are more generally found on ridges and points slightly elevated above the general surface of the country than in the valleys. Elevation, however, does not seem to have a decided influence in determining the point of discharge.

The foregoing details are brought to the attention of our readers in the hope of arousing a lively interest in, and a close observation of, the results of lightning strokes on trees.

IS THE DANGER OF LIGHTNING STROKE INCREASING?

The above question is frequently asked. Such an interrogatory is naturally suggested by real though temporary increases in one region or another, such as occurred in the Lake region in 1896. In Michigan the number of cases of damage by lightning stroke reported to the Commissioner of Insurance in 1895 was 316, covering damages amounting to $37,563. In the following year the number of cases rose to 1,509, and the damages to $143,841. There was an increase in the number of thunderstorms also, but not in so great a proportion. Unfortunately it is not possible, on account of the fragmentary and incomplete nature of the data now available for the United States, to delimit, in all cases, the regions in which such temporary increases have occurred. The writer gives it as his opinion, in the absence of specific data, that electric disturbances vary from year to year more in intensity than in frequency, although there is undoubtedly a noticeable variation in frequency also.

Statistics of thunderstorm frequency are much more complete than those of damaging lightning stroke, but since it does not appear that the one is a simple function of the other, we have not attempted to draw any conclusions respecting the alleged increase of lightning strokes from the record of thunderstorm frequency. Thunderstorm activity often begins almost simultaneously over a rather large region and it may continue intermittently for a day or so, when, without any apparent reason, there is a decided increase in the violence of the storms. Again, violent thunderstorms may occur in the same district on two successive afternoons, but this is the exception rather than the general rule. A single outburst of electrical energy, such as occurred in the State of New York, August 23 and 24, 1898, is very often sufficient to turn what would otherwise have been a normal season into one of increased destructiveness.

We have no means of determining the cause or causes of these violent manifestations of electrical phenomena. So far as we have observed they occur in connection with the movement of sluggish cyclonic areas across the country during the warmer months, May to September, inclusive. The regions liable to visitation by these manifestations are in general the Lake region, the upper and middle Mississippi Valley, and from Missouri eastward to the Atlantic. What little progressive motion they have is generally to the eastward. Not infrequently the development of unusually severe conditions takes place, as before stated, in the afternoon almost simultaneously over a considerable area. Some years are almost free from violent electrical storms, while in others they occur with considerable frequency. Rarely is there an excess of them in all parts of the country in one and the same year.

The most comprehensive statistics for the study of secular variation in damaging lightning strokes that we know of are those of the German Empire. Dr. Wm. von Bezold, as early as 1869, in a study of the statistics collected by insurance associations of Bavaria,[1] expressed the opinion that in that kingdom to the right of the Rhine there was a steady increase in danger from damaging lightning stroke. He again took up the subject in 1874[2] and in 1884,[3] finding in both cases a continuation of the increase first noted in 1869.

Dr. G. Hellmann, discussing the same subject in 1886, with particular reference to Schleswig-Holstein, Baden, and Hesse, showed that the increase already noted for other parts of Germany did not obtain in all parts of these provinces, there being localities where the danger was apparently decreasing.

The subject, as viewed from an insurance standpoint, was investigated in 1889, 1892, and 1898, by Mr. Kassner, Director Fire Insurance Associations of Middle Germany.[4]

From Mr. Kassner's compilations we learn that from 1876 to 1883, in a million insured buildings in the German Empire, 164.2 were struck by lightning; from 1884 to 1891 the number rose to 258.4. For middle Germany alone the increase was greater but the period covered by the statistics was different. From 1864 to 1876 the average number of buildings struck and damaged by lightning was 110.8; for the period, 1877 to 1889, the number was 223.1.

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[1] Poggendorff's Ann. Bd. 136. S. 513 ff. 1869.

[2] Sitzungsber. d. k. b. Akad. d. Wiss. II Cl., S. 284 ff. 1874.

[3] Abhandl. d. k. b. Akad. d. Wiss. II Cl. XIV. Bd. 1, Abth. S. 172 ff. 1884.

[4] (*a*) Ueber zündende und nichtzündende Blitze. Merseburg, 1889. (*b*) Ueber Blitzschläge in Deutschland während der Jahr 1876 bis 1891. Merseburg, 1892. (*c*) Ueber Blitzschläge in der Province Sachsen und dem Herzogthum Anhalt. 1887–1897. Merseburg, 1898.

Mr. Kassner's most recent work, from which we extract the following, refers exclusively to the province of Saxony and the duchy of Anhalt: "In the flat country there were 804 cases of damaging lightning stroke for the five years, 1887 to 1891, as against 1,088 in the five years 1893 to 1897, an increase of 35.3 per cent. On buildings in cities the increase for the corresponding period was only 27.3 per cent."

The total number of insured buildings in the open country and city, respectively, struck by lightning in the eleven years, 1887–1897, was 2,091 and 524, thus showing the danger from lightning in the country to be nearly four times as great as in the city.

A table is also given showing the number of cases both of fire-causing (zündenden) and those which do not cause fire, (kalten) strokes for each year from 1887 to 1897. In regard to the conclusions to be drawn from this table the author says: "Finally, it follows (and certainly contrary to the early observations, according to which the increase of lightning strokes not causing fire was the greatest) that the strokes causing fire have increased more than those not causing fire."

"It is particularly shown:

(*a*) In the flat country the number of strokes causing fire rose from 164 in the first five years to 239 in the last, an increase of 45.7 per cent; the number of strokes not causing fire, from 649 in the first five years to 849 in the last, an increase of but 32.7 per cent.

(*b*) In the cities, during the same time, the number of strokes causing fire rose from 21 to 30, and increase of 42.9 per cent; those not causing fire from 188 to 236, an increase of 25.5 per cent."

We note in this connection that statistics for Bavaria, quoted on page 73, show an increase of strokes which do not cause fire, a result directly opposite to the one above mentioned.

Dr. von Bezold's most recent contribution to the subject[1] is largely a continuation of his earliest studies of fire insurance statistics for Bavaria supplemented by the data of quite recent years. The statistics for Bavaria are especially well adapted to the study of either annual or long period variations since the yearly values have been reduced in all cases to a constant unit, viz, one million insured buildings. We reproduce from Dr. von Bezold's work the table given below:

---

[1] Uber die Zunahme der Blitzgefahr Während der letzten sechzig Jahre, sitzungsberichte der k. p. Akademie der Wissenschafften zu Berlin. Berlin, 1899.

TABLE VII.—*Damaging lightning strokes in the Kingdom of Bavaria for the insurance year, October of one year to September of the next, except columns* 6 *and* 7, *which are for the calendar year.*

Year.	Insured buildings in thousands.	No. of lightning strokes damaging buildings.	Number of cases per million insured buildings.		Wolf's relative sun spot numbers.	
			Actual values.	Smoothed values.	Actual values.	Smoothed values.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1833	1,021	17	16.6	....	8.5	....
1834	1,025	57	55.7	43.3	13.2	23.0
1835	1,061	48	45.3	40.0	56.9	62.2
1836	1,083	15	13.9	27.5	121.8	109.7
1837	1,085	40	36.9	27.9	138.2	125.3
1838	1,085	26	24.0	29.3	103.1	107.6
1839	1,088	35	32.2	31.7	85.8	84.5
1840	1,090	42	38.6	33.7	63.2	62.2
1841	1,095	28	25.6	27.7	36.8	40.2
1842	1,098	23	21.0	22.3	24.2	24.0
1843	1,102	24	21.8	21.6	10.7	15.2
1844	1,109	24	21.7	24.8	15.0	21.2
1845	1,115	38	34.1	34.7	40.1	39.2
1846	1,121	55	49.1	39.9	61.5	65.4
1847	1,128	31	27.5	32.4	98.4	95.6
1848	1,133	29	25.6	25.0	124.3	110.7
1849	1,136	25	22.0	24.0	95.9	95.6
1850	1,139	30	26.4	26.8	66.5	73.4
1851	1,142	37	32.4	34.1	64.5	62.4
1852	1,144	52	45.5	45.2	54.2	53.0
1853	1,144	60	57.7	47.8	39.0	38.2
1854	1,147	38	33.1	42.2	20.6	21.7
1855	1,152	52	45.1	47.5	6.7	9.6
1856	1,156	76	65.7	58.6	4.3	9.5
1857	1,159	67	57.8	58.4	22.8	26.2
1858	1,163	61	52.5	53.9	54.8	56.6
1859	1,171	62	52.9	51.2	93.8	84.5
1860	1,180	55	46.6	50.0	95.7	90.6
1861	1,183	64	54.1	51.9	77.2	77.3
1862	1,193	63	52.8	57.1	59.1	59.8
1863	1,206	83	68.8	61.3	44.0	48.5
1864	1,226	67	54.7	62.4	46.9	42.1
1865	1,244	89	71.5	59.3	30.5	31.0
1866	1,264	50	39.6	57.3	16.3	17.6
1867	1,278	99	77.5	76.7	7.3	17.0
1868	1,281	144	112.4	92.0	37.3	39.0
1869	1,292	85	65.8	76.2	73.9	81.0
1870	1,302	79	60.7	68.8	139.1	115.8
1871	1,307	115	88.0	79.3	111.2	115.8
1872	1,315	106	80.6	94.1	101.7	95.2
1873	1,328	169	127.2	105.3	66.3	69.7
1874	1,344	116	86.3	104.5	44.6	43.2
1875	1,358	161	118.6	98.3	17.1	22.5
1876	1,260	89	70.7	90 2	11.3	13.0
1877	1,279	129	100.9	89.8	12.3	9.8
1878	1,300	113	86.9	91.1	3.4	6.3
1879	1,320	119	90.2	87.5	6.0	11.9
1880	1,339	111	82.9	93.7	32.3	31.2
1881	1,357	162	119.4	103.5	54.3	50.1
1882	1,374	128	92.4	99.1	59.6	59.3
1883	1,408	130	92.3	96.6	63.7	62.6
1884	1,424	156	109.6	112.2	63.5	60.7
1885	1,440	198	137.5	143.4	52.2	48.3
1886	1,456	275	188.9	151.1	25.4	29.0
1887	1,471	131	89.1	127.9	13.1	14.6
1888	1,488	215	144.5	168.2	6.8	8.2
1889	1,503	443	294.8	221.6	6.3	6.6
1890	1.777	271	152.5	191.8	7.1	14.0
1891	1,795	300	167.2	169.3	35.6	38.0
1892	1,814	345	190.2	172.0	73.8	67.1
1893	1,835	258	140.6	154.4	85.2	79.2
1894	1,855	271	146.1	164.3	72.5	73.6
1895	1,875	421	224.5	199.0	64.0	60.2
1896	1,900	382	201.0	215.2	40.5	42.8
1897	1,926	451	234.2	....	26.3	....

The nature of the data in the several columns is generally indicated with sufficient clearness by the superscription. The smoothed values of column 5 and 7 were obtained by the formula $\frac{a+2b+c}{4}$ wherein b is the middle year and a and c the years immediately preceding and following.

We see here, as pointed out by the author, a steady increase in the danger from lightning from the first, the increase of the last ten years over the first being about sixfold. From 1833 to 1842 there were in 1,000,000 buildings 309.8 struck by lightning, an average of 31 per year; in the period 1888 to 1897, the number of buildings struck in the ten years rose to 1,895.6, an average of 190 per year, concerning which the author remarks:

> This is, at all events, a highly remarkable fact, especially in consideration of the circumstance that according to the compilations of Mr. Kassner during the period covered by his investigations, similar, and in some cases even greater increases were found for all except very inconsiderable portions of Germany. Unfortunately it is scarcely possible to express more than a conjecture as to the cause of this remarkable increase.

The compilations of the Bavarian fire insurance companies previous to 1883 did not differentiate between lightning strokes that caused fire and those which merely inflicted other damage upon the building, all cases of damage by lightning being given as loss by fire. This fact explains the substitution by von Bezold of the term *schadenblitze* (damaging lightning stroke) for *zündendeblitze* (fire-causing lightning) which it may be remembered was used in a former publication.

The following table gives the total number of strokes upon buildings, the number that caused fires, and the percentage of the latter to the whole number of strokes.

TABLE VII.—*Percentage of lightning strokes causing fire in Bavaria*, 1883–1897.

Year.	Lightning strokes.		*B* in per cent of *A*.	Year.	Lightning strokes.		*B* in per cent of A.
	A Altogether.	*B* Causing fires.			*A* Altogether.	*B* Causing fires.	
1883	130	67	51.6	1891	300	101	33.7
1884	156	64	41.1	1892	395	158	44.6
1885	198	82	41.4	1893	258	93	36.1
1886	275	97	35.3	1894	271	86	31.7
1887	131	54	41.2	1895	421	140	33.3
1888	215	78	36.3	1896	382	130	34.0
1889	443	138	31.2	1897	451	102	22.6
1890	271	92	33.9				

The figures of the above table reveal the important fact that for Bavaria, at least, while the total number of strokes has increased, the number of those which set fire to buildings has steadily diminished. We see this more clearly when we form them into 5-year means. Thus, the percentage of fire-causing strokes in the period—

1883–1887 was 42.7 per cent.
1888–1892 was 35.9 per cent.
1893–1897 was 31.5 per cent.

The author remarks that this can scarcely be considered surprising, since it is known from physical experiments that the severest discharges demolish and destroy, while the weaker and slower discharges cause fire. At any rate, it is of interest to note that with the increase in the severity of thunderstorms the so-called cold strokes increase in greater proportion than the fire-causing strokes. Of course, we should take into consideration, in connection with the last-given figures, the steady increase in the use of hard roofs; but this fact alone is not sufficient to explain the greater increase of cold strokes as compared with the strokes causing fire.

The questions here touched upon are of the greatest practical importance. Let us hope that each and everyone will contribute toward their final solution.

○

Plate I

AVERAGE ANNUAL NUMBER OF THUNDERSTORM DAYS IN THE UNITED STATES.

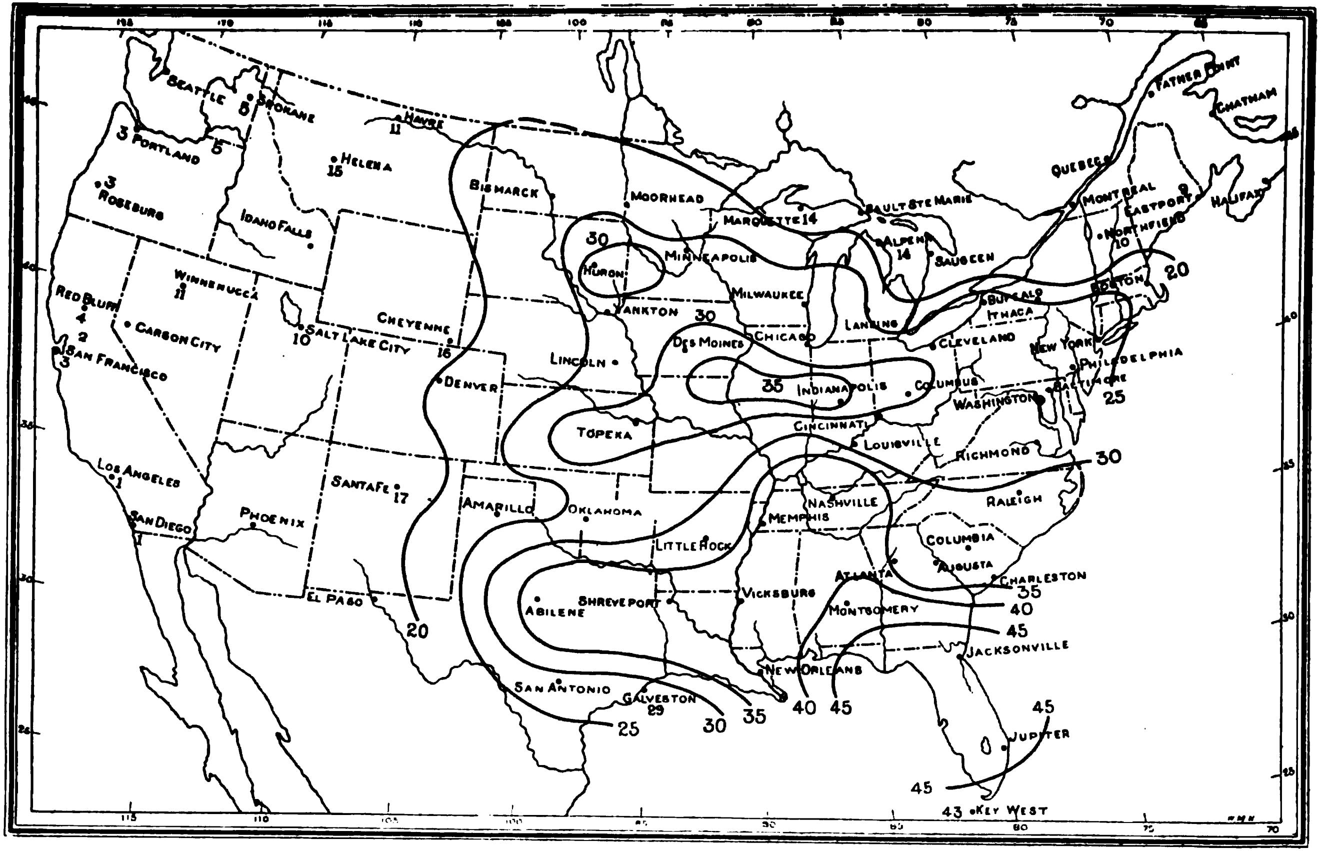


Plate II. EFFECT OF LIGHTNING STROKE ON A WALNUT TREE. Photographed by A. J. Henry.

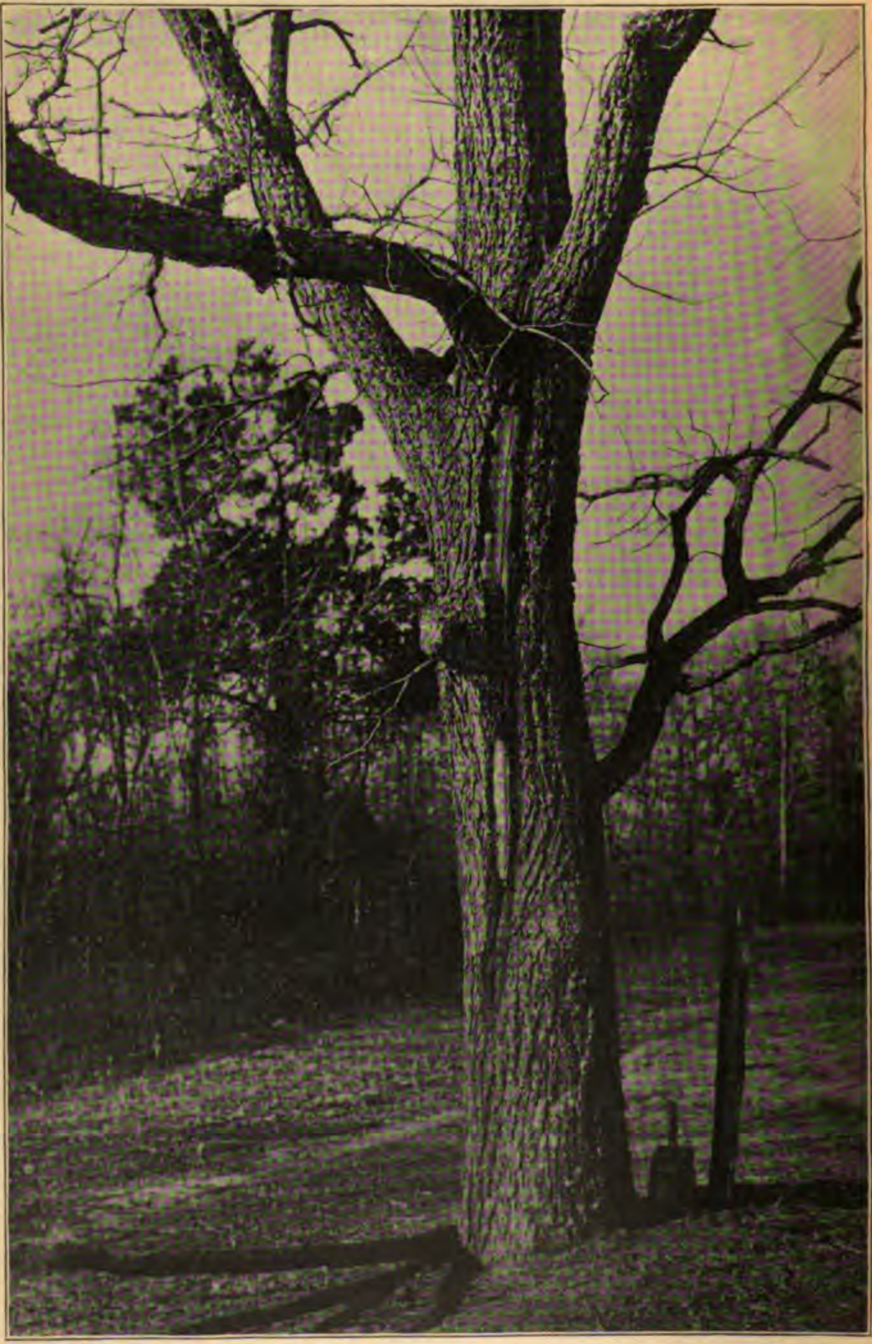


Plate III. EFFECT OF LIGHTNING STROKE ON AN OAK. Photographed by A. J. Henry.

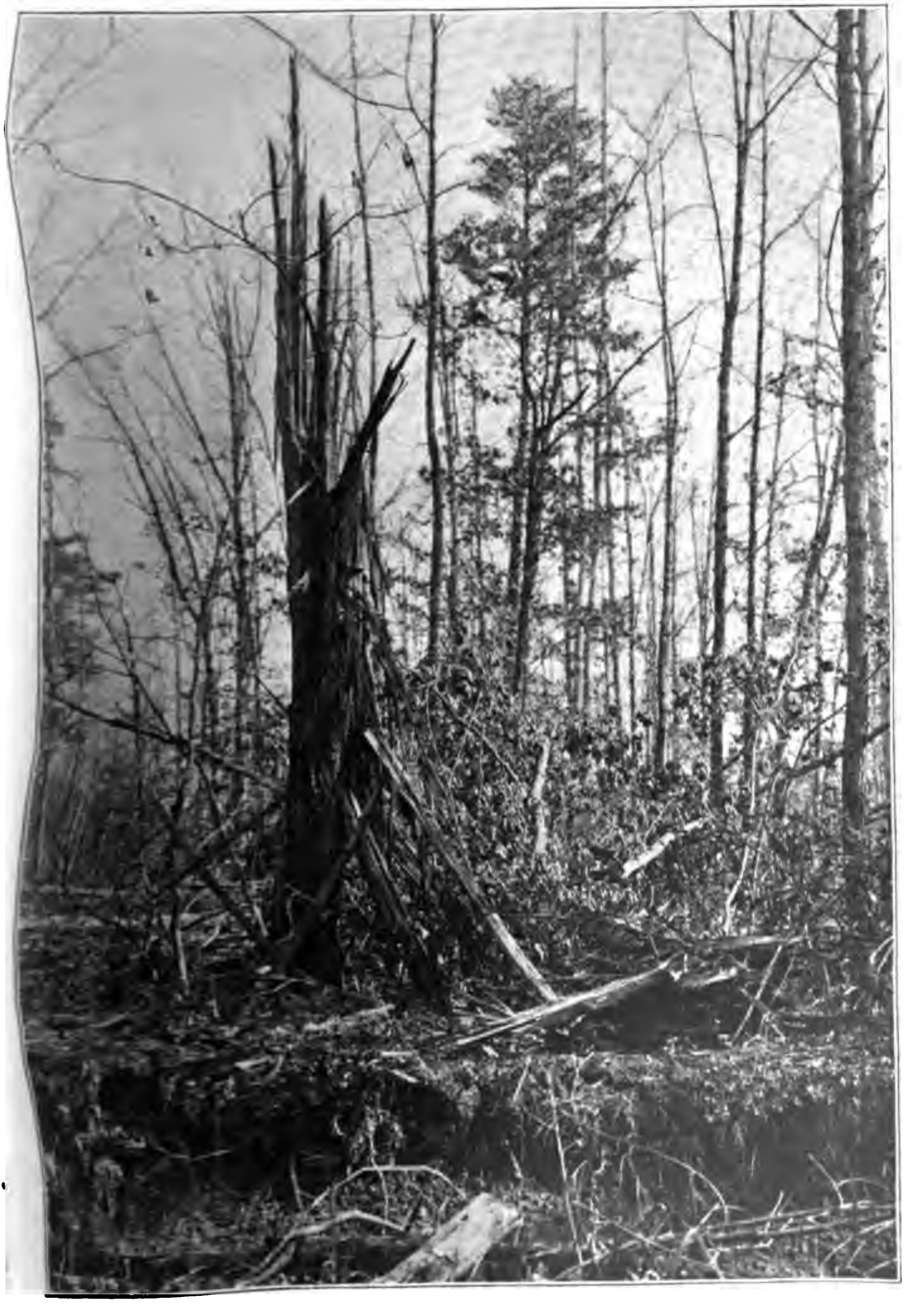
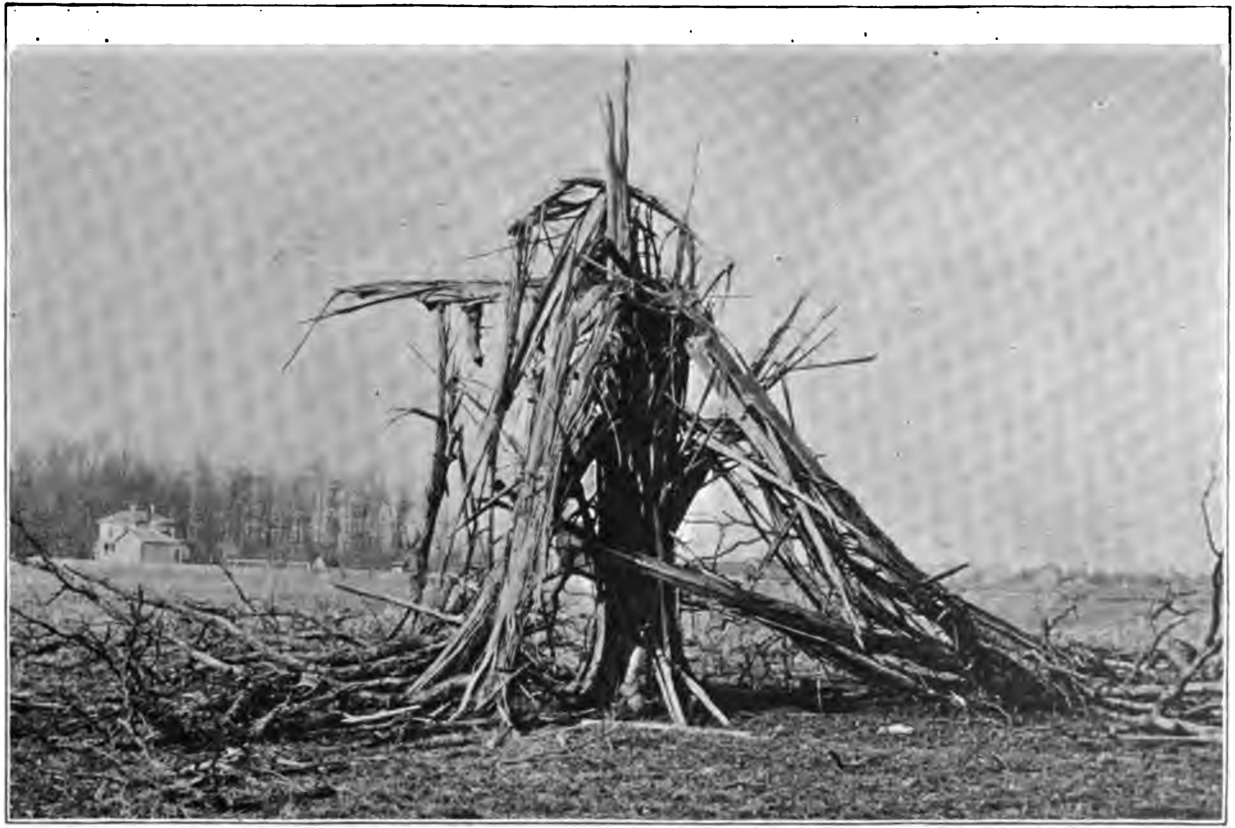


Plate IV.



BUR OAK SHATTERED BY LIGHTNING. Photographed by Frank Woodmancy.

Bulletin No. 27.—W. B. No. 209.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

The Probable State of the Sky along the Path of Total Eclipse of the Sun, May 28, 1900, Observations of 1899.

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau.

BY

FRANK H. BIGELOW,
PROFESSOR OF METEOROLOGY.

WASHINGTON:
WEATHER BUREAU.
1899.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Weather Bureau,
Washington, D. C., October 30, 1899.

The Honorable,
The Secretary of Agriculture.

Sir: I have the honor to transmit herewith a copy of the third report, covering the observations of 1899, on the Probable State of the Sky along the Path of the Total Eclipse of the Sun, May 28, 1900, by Prof. Frank H. Bigelow, and to recommend its publication as a bulletin of the Weather Bureau. Observations have been made in 1897, 1898, and 1899, to determine the prevailing average cloudiness in the districts covered by the eclipse track, and the results are here summarized for the information of astronomers and others interested in the approaching eclipse.

Very respectfully, your obedient servant,

Willis L. Moore,
Chief U. S. Weather Bureau.

Approved:
James Wilson,
Secretary.

THE PROBABLE STATE OF THE SKY ALONG THE PATH OF THE TOTAL ECLIPSE OF THE SUN, MAY 28, 1900. THIRD REPORT. OBSERVATIONS OF 1899.

By Prof. Frank H. Bigelow.

The total eclipse of the sun, which occurs on May 28, 1900, is of special interest to the people of the United States, because of its unusually convenient place of happening in the East Gulf and Middle Atlantic States. Instead of being obliged to make a long journey to the ends of the earth to view this eclipse, we are fortunate enough to have the path at home, in readily accessible localities. The cities of New Orleans, La., Mobile, Ala., Montgomery, Ala., Raleigh, N. C., and Norfolk, Va., all lie within the shadow path of totality, and this is certainly one of the most unique conditions possible, as it will enable thousands of persons to see that most wonderful spectacle of astronomy, the solar corona. Astronomers are making their preparations to locate stations along the shadow path, and to carry out an extensive series of scientific observations. With the purpose of facilitating these operations, by pointing out the most favorable localities where the sky is likely to be freer of clouds than anywhere else, the United States Weather Bureau has executed a survey of the sky for determining its probable cloudiness along this path. Since the prevailing meteorological conditions at that season of the year, May and June, have certain features by which cloudiness is more concentrated in some places than in others, it is possible to determine the facts by a systematic set of observations designed for that object. Prof. D. P. Todd suggested the importance of attempting to secure such preliminary records, and has made an application of the method to the eclipse of April 16, 1893, in Chile, and of August 9, 1896, in Japan. On previous occasions, instead of such special surveys, the available meteorological records along eclipse tracks were carefully examined, as for the eclipse of July 29, 1878, in the western territories of the United States, in order to determine the relative cloudiness, but Professor Todd's plan is more elaborate and involves special observations at the local hour of the eclipse, at many stations along the track, and requires them to be repeated during three years preceding the eclipse. The Weather Bureau has carried out this program, and possesses records from 66 stations in 1897, 88 in 1898, and 76 in 1899. This work has been done by voluntary observers who have earned the thanks of the Bureau and the public for this contribution to the subject. Before presenting the results derived for the probable cloudiness, the circumstances of the eclipse may properly be briefly stated.

THE PROBABLE STATE OF [illegible] THE TOTAL ECLIPSE OF [illegible] REPORT. OBSERVATIONS OF [illegible]

[illegible]

The total eclipse of [illegible]
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I. CIRCUMSTANCES OF THE ECLIPSE.

The astronomical data for the eclipse of May 28, 1900, are taken from the American Ephemeris and Nautical Almanac, issued about three years in advance. Chart I shows the location of the totality path, the places from which the different phases are to be seen, and the hours of occurrence. The track of totality begins on the Pacific Ocean just west of Mexico at sunrise, trends due eastward over Mexico, enters the United States very near New Orleans, La., and extends northeastward over Mobile and Montgomery, Ala., near Atlanta, Ga., over Raleigh, N. C., and leaves this country in the region of Norfolk, Va., and Cape Henry. It then crosses the Atlantic Ocean and touches Europe at Coimbra, Portugal, takes in Algiers and northern Africa, and terminates near the northern end of the Red Sea at sunset. The sun's eclipse may, therefore, be observed in the United States in the morning hours from about 7h 20m to 9h 0m local mean time, and in Spain and Africa in the afternoon after 4 o'clock.

Table I.—*A total eclipse of the sun, May 28, 1900, visible in Mexico, the East Gulf and Middle Atlantic States, in Spain, and in northern Africa.*

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension May 28d 2h 57m 2.7s.

Sun and moon's right ascension	4h 19m 47.38s.	Hourly motions, 10.16s and 149.08s.	
Sun's declination	21° 27′ 16.0″ N.	Hourly motion	0′ 24.2″ N.
Moon's declination	21 50 17.4 N.	Hourly motion	2 41.0 N.
Sun's equatorial horizontal parallax.	8.7	Sun's true semidiameter	15 46.6
Moon's equatorial horizontal parallax	58 27.4	Moon's true semidiameter	15 55.9

CIRCUMSTANCES OF THE ECLIPSE.

	Local mean time.	Longitude W. Greenwich.	Latitude N.
Eclipse begins	May 28d 5h 41.2m a. m.	97° 49.5′	9° 59.2′
Central eclipse begins	28 5 27.9 a. m.	116 38.4	17 50.3
Central eclipse at noon	28 11 57.0 a. m.	45 0.4	44 56.8
Central eclipse ends	28 6 40.0 p. m.	—31 37.1	25 20.6
Eclipse ends	28 6 25.6 p. m.	—12 29.4	17 32.8

PATH OF THE SHADOW OVER THE UNITED STATES FROM NEW ORLEANS, LA., TO NORFOLK, VA.

Number.	Time.		Northern limit of shadow path.		Central line.		Southern limit of shadow path.		Duration of totality on the central line.
	Greenwich mean time.	Local mean time.	Latitude.	Longitude.	Latitude.	Longitude.	Latitude.	Longitude.	
			° ′	° ′	° ′	° ′	° ′	° ′	
1	May 28d 1h 30m	7h 27.4m a. m.	+29 56.3	91 5.1	+29 46.5	90 39.7	+29 36.7	90 14.3	1m 12.6s
2	1 35	7 47.1	31 47.7	87 22.8	31 36.0	86 58.2	31 24.3	86 33.6	1 19.6
3	1 40	8 5.2	33 25.0	84 5.2	33 11.8	83 41.4	32 58.6	83 17.6	1 26.0
4	1 45	8 22.2	34 51.9	81 4.1	34 37.3	80 41.1	34 22.7	80 18.1	1 31.7
5	1 50	8 39.5	36 10.3	78 14.6	35 54.4	77 52.4	35 38.5	77 30.2	1 37.0
6	1 55	8 54.2	37 21.7	75 38.5	37 4.6	75 12.1	36 47.5	74 50.7	1 41.9

Table I gives the astronomical data that concerns the prediction for the United States. It is hoped that many persons will study the theory of predicting eclipses and learn to utilize the tables which are prepared for the purpose. The time of conjunction of the sun and moon, the declinations, the equatorial horizontal parallaxes, hourly motions, and semidiameters are given. These enable one to construct a diagram of the central path of the moon over the sun's disk, to show how much it overlaps, and thence to calculate the duration of obscurity. The result is that this is an eclipse of short duration, lasting from 1^m 13^s to 1^m 42^s in the United States. A long eclipse lasts from 5^m to 6^m, but these are of rare occurrence. The time and place of the beginning and ending of the eclipse on the edge of the sun, that of total obscurity, as well as the central eclipse at noon, are placed in the section headed "Circumstances of the Eclipse." These define the track from which contacts may be observed. "Eclipse begins" indicates the time and place of the earth first touching the penumbra of the moon; "central eclipse begins," that of axis of moon's shadow touching the earth; "central eclipse at noon," that of the axis of the shadow coincident with the plane of the meridian at the point of its intersection with the earth's surface; "central eclipse ends" and "eclipse ends" have corresponding converse meanings. A description of the eclipse computation is found in the American Ephemeris for 1900, pp. 525–531. The location of the shadow path in the United States is obtained from the data of the next section of Table I. The times are given in Greenwich mean time, and also in local mean time, with the corresponding latitudes and longitudes, and the duration of the totality on the central line. Thus, to find the time and place where the eclipse will last 1^m 12^s, the time is 7^h 27^m 4^s a. m., and the three pairs of coordinates for the northern, central, and southern lines fix three points nearly at right angles to the path for the given time, which applies to the central line of the totality. The position of this line is a little southwest of New Orleans, La., and it is marked 1 on Chart IV.

There are six such lines on the map, drawn across the track from northwest to southeast, at intervals of five minutes of Greenwich mean time, numbered from 1 to 6, as in Table I, first column. Stations which are located within the path and between these cross lines should interpolate proportionally for the time and duration of totality at their place, the table numbers referring to the central line, and the duration diminishing to zero upon the northern and southern limits of the shadow. It will be observed that the local hour of totality increases from west to east, beginning with 7^h and 27^m a. m. near New Orleans, La., and growing later to 8^h 50^m near Norfolk, Va., as the shadow sweeps over the country; also, the duration is 1^m 13^s near New Orleans La., and 1^m 42^s near Norfolk, Va. This fact constitutes a powerful argument for locating the stations as far eastward as possible, in North Carolina and Virginia, since the gain of half a minute is made in the duration of the totality of the eclipse, which is important when the seconds are precious for observations.

II. PROBABLE STATE OF THE SKY ALONG THE PATH IN THE UNITED STATES.

We now pass to an account of the results of the cloud observations made by the Weather Bureau to determine the relative amount of cloudiness likely to prevail along the shadow path of the eclipse. Although the plan of taking special observations for three years was suggested some time ago, and while there have been for other eclipses discussions of the available data obtained from special observations, this survey by the Weather Bureau is the first case where such work has been systematically carried out for three successive years on an adequate scale to give decisive conclusions. The results show that the record for each year affords the same general determination, and the three years harmonize well together so that no contradictory evidence has arisen to throw doubt upon the final outcome of the investigation.

The survey of the eclipse track for cloudiness during the season of 1899 has been conducted in precisely the same manner as for the years 1897 and 1898. The work was done by voluntary observers, at the suggestion of the Weather Bureau, which furnished the necessary forms and instructions for the observations. The number of reports received has been sufficient to give definite results in each of the three years.

The observations were divided into two parts: (1) On the general state of the sky, and (2) the state of the sky near the sun. On each morning there were six entries to be made in the journal, being composed of these two sets of observations, made at 8:00 a. m., 8:30 a. m., and 9:00 a. m., that is about the hour of the eclipse, The notation adopted for the respective cases was: (1) 0=sky entirely clear; 1=sky $\frac{1}{4}$ cloudy; 2=sky $\frac{1}{2}$ cloudy; 3=sky $\frac{3}{4}$ cloudy; 4=sky all cloudy; and (2) 0=sun clear from clouds; 1=sun in scattered clouds; 2=sun in a mass of clouds; 3=sun quite invisible. A complete record covered thirty-two observing days, and hence the maximum cloudiness for the three daily observations would amount to 384 for the general sky, and 288 for the sky near the sun for the entire period. Since the sum of the entries was always smaller than the maximum the percentage of the cloudiness actually observed is equal to the sum of the recorded numbers divided by 384 and 288, respectively.

Table II gives the result of the observations for 1899, computed in this manner. The first column contains the name of the stations; the second the observers' names. The figures under 8:00, 8:30, and 9:00 give the total cloudiness recorded at the respective hours during the thirty-two days of observation from May 15 to June 15, inclusive; and finally the sum of them follows. The mean of all the stations within a single State is taken and reduced to the percentages for final discussion.

It will be noted that the percentages for the second case, sky near the sun, run a little smaller than for the first case, general sky, averaging between 1 per cent and 2 per cent lower, which shows that the morning hour during this period is rather more favorable for the sky near the sun than for the rest of it, and indicates that the low altitude of the morning sun will not be an unfavorable circumstance in the Southern States. It is seen that the resulting percentages for 1899 show a diminution of cloudiness from the Atlantic coast near Norfolk, Va., toward Georgia, and also from the Gulf coast near New Orleans, La., toward the same point. This means that central Georgia and eastern Alabama, about south of Atlanta, is the most favorable part for avoiding the tendency to cloudiness, and that therefore this is the best region for locating the eclipse stations so far as that consideration is concerned.

TABLE II.

Stations.	Observers.	General state of the sky.				Sky near the sun.			
		8:00	8:30	9:00	Sum.	8:00	8:30	9:00	Sum.
Virginia.									
Nimmo[1]	L. A. Brock	49	45	42	136	37	35	32	104
Hampton	C. K. Goodrich	63	57	57	177	41	33	35	109
Onancock	J. C. Weaver	28	27	25	80	23	20	21	64
Birdsnest	C. R. Moore	53	61	63	177	37	46	43	125
Wallaceton[2]	Jno. G. Wallace	38	39	40	117	31	34	32	97
Means					137				100
Per cent of total	possible cloudiness				35.7				34.8
North Carolina.									
Gatesville	J. T. Walton	66	60	54	180	49	47	39	135
Willeyton	H. B. Cross	46	48	40	134	33	37	25	95
Winton	S. S. Daniel	42	40	42	124	30	21	25	76
Rich Square	A. S. Webb	46	45	46	137	37	33	31	101
Scotland Neck[3]	R. H. Gray	19	17	17	53	14	13	12	39
Weldon	H. S. S. Cooper	63	62	62	187	42	39	36	117
Nashville	J. B. Boddie	45	46	41	132	30	32	32	92
Springhope	Geo. W. Bunn	66	61	67	194	40	40	42	122
Louisburg	Thos. B. Wilder	42	37	33	112	25	23	20	68
Selma[1]	R. J. Noble	42	42	42	126	31	31	31	93
Auburn	Troy Poole	37	33	35	105	24	20	24	68
Raleigh	C. von Herrmann	57	57	54	168	40	40	42	162
Moncure	W. H. Thompson	30	30	22	82	25	24	21	70
Pittsboro	H. H. Merritt	46	43	36	125	35	33	27	95
Fayetteville	Frank Glover	48	46	43	137	35	31	29	95
Rockingham	J. M. Stansill	46	40	37	123	26	29	22	77
Albemarle	Green M. Dry	35	33	33	101	27	22	22	71
Wadesboro	W. K. Boggan	17	14	12	43	12	11	9	32
Monroe	T. A. Ashcroft	37	28	21	86	24	18	12	54
Means					128				88
Per cent of total	possible cloudiness				33.3				30.6
South Carolina.									
Cheraw	H. L. Powe	51	47	46	144	33	26	31	90
Lancaster	J. C. Foster	61	59	56	176	27	27	24	78
Lewis Turnout[4]	S. M. Bowdell	29	16	17	62	25	16	13	54
Winnsboro	J. W. Seigler	27	27	34	88	28	32	34	94
Little Mountain	Jno W. Sease	40	43	40	123	28	30	20	78
Santuck	E. W Jeter	27	24	20	71	25	21	21	67
Prosperity	J. Perry Cook	36	38	36	110	30	30	30	90
Newberry	Edw. Scholtz	28	35	36	99	21	23	24	68
Columbia	J. W. Bauer	55	53	44	152	45	40	35	120
Longshore	W. G. Peterson	37	36	33	106	23	25	17	65
Trenton	C. A. Long	23	23	26	72	15	13	13	41
Crosshill	E. T. McSwain	21	21	21	63	18	18	18	54
Greenwood[5]	M. M. Calhoun	28	26	28	82	15	14	15	44
Saluda	E. L. Mathis	42	43	39	124	31	24	19	74
Watts	J. W. Thomas, M. D.	45	44	38	127	33	32	33	98
Means					108				77
Per cent of total	possible cloudiness				28.1				26.7

TABLE II—*Continued.*

Stations.	Observers.	General state of the sky.				Sky near the sun.			
		8:00	8:30	9:00	Sum.	8:00	8:30	9:00	Sum.
Georgia.									
Athens	C. D. Cox	23	18	16	57	15	13	12	40
Atlanta	H. P. Hardin	26	33	32	91	22	26	24	72
Griffin	E. Lovelace	28	28	28	84	22	22	22	66
Talbotton	Wm. T. Dennis	31	33	33	97	15	16	17	48
Westpoint	T. J. Jennings	20	13	12	45	14	11	6	31
Columbus	Josephene W. Long	24	17	12	53	16	14	14	44
Means					71				50
Per cent of total	possible cloudiness				18.5				17.4
Alabama.									
Smiths Station	A. L. Frazer	35	29	31	95	21	20	20	61
Fort Mitchell	Jno. Cantry	33	34	34	101	24	24	26	74
Auburn	Jas. T. Anderson	43	39	35	117	34	31	28	93
Opelika	A. E. Barnett	29	28	29	86	28	28	29	85
Tuskegee	Geo. W. Carver	36	37	37	110	37	41	42	120
Union Springs	P. L. Cowan	23	23	26	72	24	23	24	71
Tallassee	Jno. T. Jarman	39	38	34	111	31	26	24	81
Mathews	W. D. Dillard	23	23	26	72	15	12	20	47
Troy	F. J. Cowart	28	27	30	85	18	17	18	53
Montgomery	G. E. Gardiner	38	31	29	98	32	24	23	79
Highland Home[1]	Saml. Jordan	22	17	14	53	12	8	8	28
Fort Deposit	C. E. Reid	22	11	33	66	17	19	19	55
Greenville	F. E. Dey	21	20	23	64	11	11	11	33
Castleberry	S. Castleberry	24	23	22	69	24	16	15	55
Latham	M. McGorran	18	18	18	54	13	11	13	37
Bay Minette	Mrs. M. J. Washburn	25	27	24	76	16	21	23	60
Mount Vernon	G. Becker	38	36	39	113	25	21	21	67
Citronelle	J. G. Mitchell	25	38	47	110	16	27	30	70
Means					86				65
Per cent of total	possible cloudiness				22.4				22.6
Mississippi.									
Americus	Louis V. Middleton	23	20	17	60	22	20	18	60
Ocean Springs	Thos. I. Keys	31	38	43	112	22	27	31	80
Biloxi	Jas. J. Lenore, M. D	48	42	39	129	32	25	24	81
Bay St. Louis	Bro. Isidore	51	57	62	170	26	30	37	93
Pearlington	Annette Koch	55	56	56	167	45	51	51	147
Means					148				92
Per cent of total	possible cloudiness				38.6				31.9
Louisiana.									
New Orleans	W. T. Blythe	40	50	54	144	10	25	24	59
Southern Uni'y Farm[6]	H. Jamison, Jr	4	6	6	16	2	2	2	6
Houma	Mrs. K. M. Haggerty	38	42	33	123	38	28	36	102
Schriever	C. V. Moore	32	35	35	102	24	31	36	91
Paincourtville	Jos. E. Le Blanc	34	31	35	100	24	22	25	71
Centerville	T. P. Boutte	47	49	50	146	38	34	31	103
Franklin	J. M. Bonney	53	53	53	159	37	29	37	103
Elm Hall Plains	Edw. Godcham	67	69	54	190	35	29	23	87
Means					138				88
Per cent of total	possible cloudiness				35.9				30.6

[1] One day missing. [2] Four days missing. [3] Twenty-one days missing. [4] Three days missing. [5] Eleven days missing. [6] Twenty-three days missing.

In order to exhibit the data more fully in reference to the local conditions the data of Table II is transferred to Chart II. The figures under the name of the station are for the general sky on the left and near the sun on the right, and they may indicate to some extent the favored localities within each State. The chart shows the position of the stations and the northern and southern limits of the eclipse track in the several States, and it is therefore a complete diagram of the eclipse track.

The outcome of the cloud survey for 1899 leads us to conclude that the elevated ground of Georgia and eastern Alabama, which is higher above the sea level than any other portion of the track and as remote from the coast line as possible, has the minimum of cloudiness for that region. The month of May in the southeastern districts of the United States is relatively free from clouds, and on the whole it is a good time and place for eclipse work. Since the average cloudiness is about 16 per cent in Georgia, it follows that astronomers have one chance in six against them if they locate their stations in that State, whereas if they should locate on the coast in either direction, the percentage rises to 35 or 40, and the chances are then two to five against them. It is needless to remark that any special cyclonic disturbance on May 28, 1900, might seriously modify this calculation. It will be remembered that precisely the same conclusion was reached for the preceding years of observation, 1897 and 1898, and we can say that the evidence from the cloud survey is uniformly in favor of that locality. The following Table III recapitulates the results of the three years' work and brings this fact out very clearly.

TABLE III.—*Summary of results for three years.*

(The figures are percentages of cloudiness.)

State.	1897.		1898.		1899.		Means.	
	General sky.	Near sun.	General sky.	Near sun.	General sky.	Near sun.	General sky.	Near sun.
Virginia	....	....	44.9	41.7	35.7	34.3	40.3	38.0
North Carolina	35.8	33.3	28.2	25.7	33.3	30.6	32.4	29.9
South Carolina	33.7	32.1	17.5	16.0	28.1	26.7	26.4	24.9
Georgia	18.4	16.0	12.2	10.8	18.5	17.4	16.4	14.7
Alabama	15.2	14.9	17.1	15.7	22.4	22.6	18.2	17.7
Mississippi	....	....	28.0	26.4	33.6	31.9	30.8	29.2
Louisiana	26.5	21.5	36.4	30.9	35.9	30.6	32.9	27.7

In order to deal with the observations at the several stations with the object of showing what advantages, if any, individual localities in any district may afford, the data for the three years has been collected together, and it is put in Table IV.

In the column of stations some names are printed in heavy-faced type. These are the stations which are located very near the central line of the path, and are on that account favorably placed for the observations. They are the stations to which attention would naturally first be given. It should be stated, of course, that this list does not exclude many other stations which are equally suitable for the eclipse work. The stations mentioned are those from which the Weather Bureau has received reports more or less complete, either regarding the cloudiness or the local conditions, summarized in Table V, and therefore are especially mentioned in this report. Some stations have furnished topographical reports, but nothing regarding cloudiness; such are indicated by a number and a letter, as *15a*. The second column gives a station number; the third, the number of years of observation at each place; the fourth, the average cloudiness observed, being the mean of the number of years, for the general sky; and the fifth for the sky near the sun. It should be remembered that three observations daily were combined for the thirty-two observing days in each year to produce these columns, so that a complete report for the three years would contain 288 observations. Hence, for stations reporting three years, each of the numbers against a station is the mean value of 288 observations; those reporting for two years 192, and for one year 96 individual observations. The numbers in Table IV are, therefore, of considerable weight, and may serve to distinguish accurately the relative cloudiness of the sky at the different stations even within the same State.

TABLE IV.—*Summary of the surveys for cloudiness in the years* 1897, 1898, 1899.

Stations.	Station number.	Years of record.	General sky.	Near sun.
VIRGINIA.				
Cape Henry	1	2	207	182
Nimmo	2	1	136	104
Hampton	3	2	184	112
Norfolk	4	2	174	130
Onancock	5	2	225	91
Birdsnest	6	2	199	135
Wallaceton	7	2	147	112
Indika	8	1	105	59
NORTH CAROLINA.				
Gatesville	9	3	161	108
Willeyton	10	3	147	106
Winton	11	3	133	66
Rich Square	12	1	137	101
Scotland Neck	13	2	87	71
Tarboro	14	1	162	116
Weldon	15	3	165	106
Aberdeen	15a	.....	.....	.....
Rockymount	16	2	132	96
Wilson	17	2	98	62
Nashville	18	2	176	124
Springhope	19	3	174	114
Louisburg	20	3	110	61
Selma	21	3	119	90
Auburn	22	3	116	72
Raleigh	23	3	177	123
Moncure	24	3	104	76
Pittsboro	25	3	133	97
Fayetteville	26	3	128	90
Laurinsburg	27	2	84	67
Rockingham	28	3	114	62
Albemarle	29	2	99	60
Wadesboro	30	3	52	35
Monroe	31	3	101	72
SOUTH CAROLINA.				
Cheraw	32	3	133	91
Lancaster	33	3	157	83
Lewis	34	2	59	54
Winnsboro	35	1	88	94
Little Mountain	36	3	133	82
Santuck	37	3	89	67
Prosperity	38	3	89	71
Newberry	39	1	99	68
Columbia	40	2	122	94
Chappels	41	1	69	41
Longshore	42	2	95	51
Trenton	43	3	60	36
Crosshill	44	3	70	58
Hodges	45	1	59	40
Greenwood	46	3	72	55
Saluda	47	3	112	72
Troy	48	2	165	92
Watts	49	2	90	70
Mount Carmel	50	2	56	54
GEORGIA.				
Leverett	51	1	92	58
Carmack	52	2	46	33
GEORGIA—Continued.				
Elberton	53	1	42	33
Crawfordsville	54	2	104	49
Greensboro	54a	.....	.....	.....
Madison	54b	.....	.....	.....
Athens	55	3	67	39
Macon	56	1	27	24
Covington	57	2	51	60
Atlanta	58	2	86	65
Barnsville	58a	.....	.....	.....
Griffin	59	2	62	45
Zebulon	59a	.....	.....	.....
Talbotton	60	3	84	36
Westpoint	61	3	84	23
Columbus	62	3	49	40
ALABAMA.				
Smiths Station	63	3	70	52
Fort Mitchell	64	3	90	63
Auburn	65	3	80	65
Opelika	66	1	86	85
Lochapoka	67	2	64	85
Tuskegee	68	1	110	120
Union Springs	69	3	71	65
Tallassee	70	3	88	67
Matthews	71	3	55	40
Troy	72	1	85	53
Montgomery	73	3	70	57
Highland Home	74	3	44	19
Fort Deposit	75	3	48	31
Greenville	76	3	42	24
Pineapple	77	2	83	78
Castleberry	78	3	58	50
Monroeville	78a	.....	.....	.....
Latham	79	3	49	24
Bay Minette	80	3	81	65
Mount Vernon	81	3	108	68
Mobile	82	2	86	39
Citronelle	82	3	78	44
MISSISSIPPI.				
Leakesville	84	1	46	47
Americus	85	2	90	83
Ocean Springs	86	2	68	49
Biloxi	87	2	137	76
Bay St. Louis	88	2	148	60
Pearlington	89	2	101	157
LOUISIANA.				
Poydras	90	2	186	47
New Orleans	91	3	147	68
Southern University Farm	92	1	127	80
Houma	93	3	108	73
Schriever	94	1	102	91
Napoleonville	95	1	144	89
Paincourtville	96	3	108	83
Centerville	97	1	70	82
Franklin	98	3	157	110
Elm Hall Plain	99	1	190	87

In order to exhibit this feature more fully the values from the second column, sky near the sun, are plotted on Chart III, for the stations in heavy type, that is for those near the center of the shadow. On the line of abscissas is the path of totality extending from Louisiana on the left to Virginia on the right. The vertical scale is arbitrary and represents the cloud numbers. At the proper point of the axis of abscissas representing relative longitudes, the cloud number is plotted at the suitable height on the ordinate, and near it is placed the number of the station as assigned on Table IV. Thus Cape Henry (1) has for the sky near the sun for the average of two years' observations 132, which is plotted at that ordinate; Nimmo, Va. (2), has 104 for one year; Norfolk, Va. (4), 130 for two years, &c. After plotting these numbers a mean line was drawn by free hand through the set, as shown on Chart III. This line indicates very distinctly that the minimum of the average relative cloudiness is in Georgia and eastern Alabama, as heretofore stated, and it emphasizes the conclusion reached in each of the years 1897, 1898, 1899, separately. Now, by comparing the ordinate of each station with the curved line in its neighborhood, some idea can be gained as to its local cloudy tendency. It may be said that Tuskegee, Ala. (68), and Pearlington, Miss. (89), seem to be quite abnormal, the former being observed for one year and the latter for two years. These observers may have had some personal equation in their estimates. The stations 71 to 79 seem to be especially free from regular cloudiness at the 8 a. m. to 9 a. m. hour, in the season of the year from May 15 to June 15. This chart is given for what it is worth to astronomers, and for their guidance.

The location of the eclipse track in the United States, and the position of the meteorological observing stations are given on Chart IV, The Eclipse Track and Observing Stations in the United States. It has been prepared by the Weather Bureau from maps and from the data of the American Nautical Almanac. While the scale is rather small, it yet gives quite accurately the position of some of the stations in the shadow path. The location of the other stations can be entered by reference to a large atlas, or by using the latitudes and longitudes given in Table V. The astronomical data for points on the track at 6 places on each line is to be found in Table I. The positions for five minute intervals, Greenwich mean time, of the durations of totality belonging thereto, are indicated by transverse lines at those places, together with the local mean time of the occurrence. These lines are numbered from 1 to 6, and should be compared with the first column of Table I.

A circular letter was sent out by the Chief of the Weather Bureau to a number of selected towns located near the central line of the shadow, soliciting a brief report in reply to certain questions regarding the station, which would answer the most important inquiries likely to arise in selecting sites for the eclipse stations. These questions concern the (1) latitude, (2) longitude, (3) altitude, (4) population, (5) accommodations for visitors, (6) the railroad communications, (7) the topography of the place and immediate vicinity, (8) the condition of the eastern horizon as to smoke and fog, (9) the direction of the prevailing wind and drift of smoke at the morning hour, (10) suggestions regarding available sites for observations of the early morning sun to which heavy baggage can be carried. The replies are herewith presented nearly in the language of the authors who wrote them. Astronomers will be glad to recognize the courtesy of these persons in providing them with accurate information not otherwise to be readily obtained. It is proper to say that many replies were accompanied by personal letters, offering the most cordial hospitality to all visiting astronomers, and all possible assistance in locating their apparatus.

TABLE V.—*Local circumstances at several stations near the center of the shadow path.*

4.—NORFOLK, VA.

Latitude	36° 51′ 50.59″. City Hall; Coast and Geodetic Survey.
Longitude	76° 17′ 19.95″.
Altitude	11 feet.
Population	65,000.
Accommodations	Ample; 5 hotels.
Railroads	C. & O.; N. & W.; N. Y., P. & N.; S. A. L.; A. C. L.; Southern; N. & C.; N. & S.; A. & D.; Va. B. & S.
Steamers	Regular lines to Boston, Providence, New York, Philadelphia, Baltimore, Washington, Savannah, Liverpool, Hamburg.
Topography	On Elizabeth River; no hills.
Eastern horizon	Usually clear; not likely to be misty or smoky.
Wind; drift	From south; smoke drifts north.
Suggested site	Virginia Beach (latitude, 36° 51′; longitude, 76° 2′) on the coast line; has hotel, 300 rooms, fine table; broad-gage railroad connecting with all the roads at Norfolk; full facilities for handling heavy baggage.

11.—WINTON, N. C.

Latitude	36° 24′.
Longitude	76° 58′ 30″.
Altitude	65 feet.
Population	1,000.
Accommodations	For 150.
Railroads	Nearest railroad station 3 miles distant.
Topography	Chowan River on north side of town; no hills or plateau.
Eastern horizon	Variable; sometimes misty, sometimes smoky.
Wind; drift	Drift is generally toward the east.
Suggested site	Winton, by the river steamer.

13.—SCOTLAND NECK, N. C.

Latitude	36° 06′ 30″.
Longitude	77° 24′.
Altitude	60 feet.
Population	1,500.
Accommodations	Good.
Railroads	Branch line from Atlantic Coast Line runs by Scotland Neck to Kingston, N. C.; Norfolk and Carolina runs about six miles from Scotland Neck.
Topography	Level country; Roanoke River about six miles distant.
Eastern horizon	Clear.
Wind; drift	Changeable.
Suggested site	None.

15*a*.—ABERDEEN, N. C.

Latitude	35° 08′ 32″.
Longitude	79° 25′ 30″; 72 miles south-southwest of Raleigh.
Altitude	200 feet.
Population	600.
Accommodations	Two hotels, 2 boarding houses, for 75 guests.
Railroads	S. A. L , and the A. & A., connecting with the Southern at High Point, N. C.
Topography	Shaws Ridge 2 miles east of the divide between the Cape Fear and the Pedee rivers.
Eastern horizon	Fair.
Wind; drift	No certainty,
Suggested site	Thomas's Vineyards, 3 miles northeast of Aberdeen.

16.—ROCKYMOUNT, N. C.

Latitude	35° 55′ 20″.
Longitude	77° 50′.
Altitude	102 feet; Coast and Geodetic Survey.
Population	4,200.
Accommodations	Seven hotels.
Railroads	A. C. L and Southern.
Topography	Tar River on north side of the town.
Eastern horizon	Misty, if atmosphere is damp.
Wind; drift	From south and southwest.
Suggested site	Can be seen as easily from the town as any point near by.

19.—SPRINGHOPE, N. C.

Latitude	35° 56′.
Longitude	78° 11′.
Altitude	250 feet.
Population	Between 800 and 1,000.
Accommodations	25 to 50 persons.
Railroads	One railroad at Springhope, but the best of connections at Rockymount, 30 minutes distant by rail; 2 trains daily.
Topography	Tar River is about 2 miles south. The highest point in the county is 3 miles from Springhope.
Eastern horizon	Likely to be fair at the season of the eclipse.
Wind; drift	From south or southeast.
Suggested site	None.

22.—AUBURN, N. C.

Latitude	35° 41′ 30″.
Longitude	78° 33′; 9 miles southeast of Raleigh.
Altitude	350 feet.
Population	100.
Accommodations	No hotel, but lodgings in private families.
Railroads	Southern; connects at Raleigh with S. A. L., and at Selma with A. C. L.
Topography	Neuse River is 3 miles northeast.
Eastern horizon	1897, May 28, clear; 1898, May 28, cloudy and foggy; 1899, May 28, perfectly clear.
Wind; drift	From southwest.
Suggested site	A hill easily accessible; 300 yards east of station.

23.—RALEIGH, N. C.

Latitude	25° 48′.	Weather Bureau; Coast and Geodetic Survey.
Longitude	78° 39′ 6.12″.	
Altitude	375 feet.	
Population	16,000.	
Accommodations	One first-class hotel for 300; 3 second-class hotels; numerous boarding houses.	
Railroads	S. A. L. and Southern; good connections with Washington, D. C.; Norfolk, Va.; Wilmington, N. C.; and Atlanta, Ga.	
Topography	The Neuse River, a small stream 6 miles east. No hills in vicinity, except very moderate elevations to the west.	

RALEIGH, N. C.—*Continued.*

Eastern horizon	No trouble from smoke, but likely to be hazy or misty.
Wind; drift	From southwest.
Suggested site	Elevation on which fair grounds stands. The best sites are west of the city, but it is thought there will not be smoke enough to interfere. All elevations slight, and points east of city commanding clear horizon are 1 or 2 miles from station. During the past twelve years the sky at Raleigh has been perfectly clear at 8 a. m. May 28 four times.

28.—ROCKINGHAM, N. C.

Latitude	34° 59′.
Longitude	79° 45′.
Altitude	210 feet. Coast and Geodetic Survey.
Population	2,000.
Accommodations	One large hotel; 1 medium size; 1 small.
Railroads	S. A. L. Connecting with all points twice daily.
Typography	Pee Dee River 6 miles west; numerous hills to the north and west of the town with level land to the south and east.
Eastern horizon	Generally bright unless there are clouds.
Wind; drift	From the west.
Suggested site	Place 4 or 5 miles southeast from railroad, 413 feet high; or else Ropers Mountain 10 miles north from railroad, 600 feet high; or else near railroad, which is 274 feet high.

33.—LANCASTER, S. C.

Latitude	34° 41′.
Longitude	80° 47′.
Altitude	550 feet.
Population	2,500.
Accommodations	Hotel for 100, and three boarding houses for 50.
Railroads	O. C., with S. A. L. at Rockhill, S. C., and Southern at Camden; Lancaster & Chester with Southern and S. A. L. at Chester.
Topography	Catawba River west; high hills in all directions; broad plateau 5 miles south.
Eastern horizon	Clear.
Wind; drift	Generally calm; if blowing, from the southwest or southeast.
Suggested site	Hills to southwest, or plateau to south, each directly on railroad.

38.—PROSPERITY, S. C.

Latitude	34° 13′ 30″.
Longitude	81° 34′.
Altitude	551 feet. Coast and Geodetic Survey.
Population	1,000.
Accommodations	Ample.
Railroads	Southern; S. A. L.; A. C. L.
Topography	Saluda River, Bush River; Little Mountain 7 miles away.
Eastern horizon	Very clear.
Wind; drift	From the southwest.
Suggested site	Buzzards Hill, 2 miles from town; or else a hill in the town 100 feet above surrounding country; or Little Mountain, half hour distant by train.

39.—NEWBERRY, S. C.

Latitude	34° 16′.
Longitude	81° 39′.
Altitude	502 feet. Coast and Geodetic Survey.
Population	6,000.
Accommodations	Two good hotels.
Railroads	Southern; S. A. L.; good connections in all directions.
Topography	Little Mountain is 15 miles southeast; country rolling except to the north, where it is level.

NEWBERRY, S. C.—*Continued.*

Eastern horizon	Not likely to be misty or smoky.
Wind; drift	No prevailing wind.
Suggested site	Little Mountain, on S. A. L., 1 mile from station named Little Mountain. The top is free from timber, and 400 to 500 feet above the surrounding country. Also suitable sites in the town of Newberry; Newberry College is in this town.

41.—CHAPPELS, S. C.

Latitude	34° 11′.
Longitude	81° 52′.
Altitude	402 feet. Coast and Geodetic Survey.
Population	125.
Accommodations	One boarding house.
Railroads	Southern.
Topography	Saluda River; Scurry Hill and Chappels Hill; Boarman plateau 1 mile north.
Eastern horizon	Generally clear and unobstructed.
Wind; drift	From the west.
Suggested site	Scurry Hill.

44.—CROSSHILL, S. C.

Latitude	34° 19′.	Geological Survey.
Longitude	81° 58′.	
Altitude	550.	
Population	500 to 600.	
Accommodations	Good hotel, but not large; fine hotel at Harris Springs, a summer resort, 5 miles distant.	
Railroads	S. A. L. Good connections at Greenwood, 15 miles; and at Clinton, 15 miles in the opposite direction.	
Typography	The Saluda River is 5 miles distant. No mountains. Harris Hotel, 5 miles northeast, is on quite an elevation.	
Eastern horizon	Usually clear in the latter part of May.	
Wind; drift	Seldom much wind in the early mornings of May.	
Suggested site	Harris Hotel; heavy baggage can be carried on wagons.	

48.—TROY, S. C.

Latitude	33° 59′.	Geological Survey.
Longitude	82° 18′.	
Altitude	520 feet.	
Population	400.	
Accommodations	One hotel.	
Railroads	C. & W. C. connects with Southern and with S. A. L.	
Topography	Savannah River. One small mountain 560 feet.	
Eastern horizon		
Wind; drift		
Suggested site		

51.—LEVERETT, GA.

Latitude	33° 48′.	Geological Survey.
Longitude	82° 23′.	
Altitude	420 feet.	
Population		
Accommodations	No hotel.	
Railroads	15 miles from any railroad.	
Topography	Flat Hill near, 455 feet.	
Eastern horizon		
Wind; drift		
Suggested sites		

54.—CRAWFORDSVILLE, GA.

Latitude	33° 28′ 30″.
Longitude	82° 52′.

CRAWFORDSVILLE, GA.—*Continued.*

Altitude	604 feet. Coast and Geodetic Survey.
Population	800.
Accommodations	Good.
Railroads	Ga., connecting with Southern at Atlanta and other railroads to the north and west.
Topography	No rivers; no mountains; several hills from which good views can be had.
Eastern horizon	Usually clear in May-June.
Wind; drift	Very little wind at the morning hour.
Suggested site	None specified.

54 *a*.—GREENSBORO, GA.

Latitude	33° 32′.
Longitude	83° 12′.
Altitude	750 feet.
Population	1,700.
Accommodations	One good hotel; several boarding houses.
Railroads	Ga., connecting with Atlanta and Augusta.
Topography	Oconee River to west-southwest.
Eastern horizon	Usually clear; if not clear, smoky.
Wind; drift	From the southwest.
Suggested site	None mentioned.

54 *b*.—MADISON, GA.

Latitude	33° 33′.
Longitude	83° 29′.
Altitude	1,000 feet.
Population	3,000.
Accommodations	For 100 guests at hotels.
Railroads	Ga. and Cent. of Ga., connecting with Atlanta, Augusta, Macon, and Athens.
Topography	Oconee River 13 miles east, on Ga. R. R.
Eastern horizon	Fair and clear.
Wind; drift	From the west and southwest; to the east and northeast.
Suggested site	Shousi's Hill, 5 miles northwest.

58 *a*.—BARNESVILLE, GA.

Latitude	33° 01′.
Longitude	84° 09′.
Altitude	875 feet. Coast and Geodetic Survey.
Population	3,000.
Accommodations	Good.
Railroads	Good connections.
Topography	No river; no hills; Hog Mountains.
Eastern horizon	Smoky in spring.
Wind; drift	From the northwest.
Suggested site	On Hog Mountain.

59 *a*.—ZEBULON, GA.

Latitude	33° 05′.
Longitude	84° 20′.
Altitude	800 feet.
Population	400.
Accommodations	Two hotels.
Railroads	The A. & F., controlled by Southern, and connecting with the Ga. M., and Cent. of Ga.
Topography	Generally hilly. The Flint River west; mountain systems lying west and east.
Eastern horizon	Somewhat smoky owing to the continued mountain fires.
Wind; drift	Generally from the southwest.
Suggested site	Barnesville, Thomaston, on above-named railroads. Zebulon is 50 miles south of Atlanta, and is one of the highest points between the seaboard and the mountain systems of Georgia.

60.—TALBOTTON, GA.

Latitude	32° 39′.
Longitude	84° 32′ 30″.
Altitude	750 feet.
Population	1,300.
Accommodations	Two good hotels.
Railroads	Talbotton connects with the Cent. of Ga. at Bostick, 7 miles distant, between Macon and Columbus, Ga.
Topography	Flint River east; Oak Mountain 8 to 12 miles north-northwest; Pine Mountain 12 to 18 miles north; hill 1 mile south.
Eastern horizon	Seldom misty at this season; sometimes smoky.
Wind; drift	From the south and southwest.
Suggested site	The country is rolling and there are several good locations for seeing the morning sun.

62.—COLUMBUS, GA.

Latitude	32° 26′ 30″.
Longitude	85° 00′.
Altitude	260 feet. Coast and Geodetic Survey.
Population	20,000.
Accommodations	Good hotels.
Railroads	Cent. of Ga. connects with Savannah and Atlanta; Southern connects with Atlanta; Ga. & Ala. connects with Montgomery and Jacksonville.
Topography	Chattahoochee River; no mountains; Alabama hills to the west; Rose Hill north; Wynton Hill east; city is on a plateau.
Eastern horizon	Smoky.
Wind; drift	From the west.
Suggested site	On the Alabama hills for the morning sun.

63.—SMITHS STATION, ALA.

Latitude	32° 29′.
Longitude	85° 05′.
Altitude	800 feet.
Population	50.
Accommodations	No hotels.
Railroads	Cent. of Ga.
Topography	Chattahoochee River.
Eastern horizon	Clear.
Wind; drift	From the southeast or southwest.
Suggested site	The country is flat.

69.—UNION SPRINGS, ALA.

Latitude	32° 08′.
Longitude	85° 45′.
Altitude	485 feet. Coast and Geodetic Survey.
Population	3,000.
Accommodations	Two large hotels with 40 rooms; several good boarding houses.
Railroads	M. & G. crosses the Cent. of Ga. system; 8 trains daily.
Topography	Situated on Chunnuggee Ridge near headwaters of tributaries of four water systems.
Eastern horizon	Very clear, except during general cloudiness.
Wind; drift	Generally calm in morning with smoke ascending vertically upward.
Suggested site	At highest point 1 mile from station, where conditions are favorable.

71.—MATTHEWS, ALA.

Latitude	32° 16′.
Longitude	86° 00′.
Altitude	262 feet. Coast and Geodetic Survey.
Population	200.
Accommodations	No hotel.

MATTHEWS, ALA.—*Continued.*

Railroads	Cent. of Ga.; 2 trains daily.
Topography	Level country.
Eastern horizon	Generally clear in May and June.
Wind; drift	Variable.
Suggested site	Country is slightly rolling, and there is an elevation of about 75 feet one mile from station, but near railroad.

76.—GREENVILLE, ALA.

Latitude	31° 50′.
Longitude	86° 37′.
Altitude	300 feet.
Population	3,500.
Accommodations	Two hotels and several boarding houses.
Railroads	L. & N.
Topography	Town is high, and slopes to the north and east; no rivers or mountains.
Eastern horizon	Usually clear; never misty or hazy in the spring.
Wind; drift	Usually from the southwest.
Suggested site	Plenty of good sites on the eastern edge of the town, all conveniently located.

78*a*.—MONROEVILLE, ALA.

Latitude	31° 31′.
Longitude	87° 20′.
Altitude	800 feet.
Population	500.
Accommodations	Three good hotels.
Railroads	S. Ala. connects with L. & N.
Topography	Alabama River 14 miles west; hills 4 miles northwest. Monroeville is on a plateau about 500 feet above sea level.
Eastern horizon	Generally very clear.
Wind; drift	No smoke or fogs.
Suggested site	At Monroeville, one of the highest points on the Southern Alabama Railroad.

79.—LATHAM, ALA.

Latitude	31° 04′.
Longitude	87° 52′.
Altitude	100 feet.
Population	100.
Accommodations	No hotel; good lodging in private house.
Railroads	Not on any railroad. There is a daily stage line from Bay Minette on the L. & N.
Topography	Alabama River 4 miles west.
Eastern horizon	Generally perfectly clear.
Wind; drift	Toward northwest; very little smoke here.
Suggested site	An elevation 1 mile east of village.

81.—MOUNT VERNON, ALA.

Latitude	31° 04′.
Longitude	88° 02′.
Altitude	49 feet.
Population	500.
Accommodations	Two private boarding houses.
Railroads	M. & B., connecting with Southern at Selma, with L. & N., and M. & O., at Mobile, Ala.
Topography	Mobile River to southeast.
Eastern horizon	Misty.
Wind; drift	From the southwest.
Suggested site	At Mount Vernon Barracks on a hill 180 feet high, ½ mile from station, and about 140 feet higher than the railroad. There is a tower about 100 feet high on this hill.

82.—MOBILE, ALA.

Latitude	30° 41′ 20.61″. Christ Episcopal Church spire; Coast and Geodetic Survey.
Longitude	88° 02′ 27.89″.
Altitude	14 feet; top of Spring Hill is 205 feet.
Population	40,000.
Accommodations	Ample. Also at suburb, Spring Hill.
Railroads	L. & N. to New Orleans and to Cincinnati; M. & O. to St. Louis; M. & B. to Birmingham, Ala.
Topography	Mobile River and Bay to the east and south. No elevation except Spring Hill, 5 miles west.
Eastern horizon	Great tendency to fog, haze, or smoke near the horizon in the morning.
Wind; drift	Winds prevail from the south, increasing between 8 a. m. and 9 a. m.
Suggested site	Spring Hill, easily accessible by electric cars, less subject to vibrations of travel than the city. There is less fog and haze here than in Mobile.

85.—AMERICUS, MISS.

Latitude	30° 44′.
Longitude	88° 33′.
Altitude	60 feet.
Population	100.
Accommodations	Lodging in one private house.
Railroads	It is 10 miles to McCrary station on the M., J. & K. C.
Topography	Pascagoula River 7 miles west; Escatawpa River 4 miles east; no important elevations.
Eastern horizon	Generally clear.
Wind; drift	From the Gulf of Mexico, generally from south or southwest.
Suggested site	None specified.

88.—BAY ST. LOUIS, MISS.

Station of 1850 on shore of west entrance of bay, 1 mile southwest of steamboat wharf. Pine log 18 inches in diameter with copper tack in top. Coast and Geodetic Survey.

Latitude	30° 21′ 53.30″.
Longitude	89° 21′ 25.42″.
Altitude	24 feet.
Population	3,000.
Accommodations	Hotels for 500.
Railroads	L. & N. connects with all principal points.
Topography	Jordan and Wolf rivers.
Eastern horizon	Generally clear; a little misty before sunrise.
Wind; drift	From the south and southeast.
Suggested site	The open sea is to the eastward and the view is unobstructed for the morning sun.

89.—PEARLINGTON, MISS.

Latitude	30° 13′ 4″.
Longitude	89° 34′ 30″.
Altitude	5 feet.
Population	1,500.
Accommodations	One boarding house.
Railroads	L. & N. connects with New Orleans and Bay St. Louis.
Topography	Pearl River flows through the town. The country is almost level and covered with pine timber.
Eastern horizon	Likely to be clear after 6 a. m. or 7 a. m.
Wind; drift	From the southwest.
Suggested site	English Lookout, a small station on the L. & N. railroad; the lighthouse at Rigolis.

91.—NEW ORLEANS, LA.

Latitude	29° 57′ 32.04″. St. Louis Cathedral; Coast and Geodetic Survey.
Longitude	90° 03′ 47.83″.
Altitude	10 to 20 feet.

NEW ORLEANS, LA.—*Continued.*

Population	300,000.
Accommodations	Ample and excellent.
Railroads	I. C.; L. & N.; N. O. & N. E., and others. Connections with all points.
Topography	On the Mississippi River; flat and unbroken country.
Eastern horizon	Generally clear; occasionally low fogs on the river.
Wind; drift	From the southeast.
Suggested site	Customhouse; any point on the levee along the city front; at West End, 7 miles north of city on Lake Ponchartrain.

93.—HOUMA, LA.

Latitude	29° 34′.
Longitude	90° 45′.
Altitude	9 feet.
Population	1,600.
Accommodations	Five hotels.
Railroads	Houma Branch, connecting with the Southern Pacific at Schriever.
Topography	Flat and level country; Bayou Terre Bonne to the north, running at this point east and west.
Eastern horizon	Generally clear, bright sky, seldom misty or smoky.
Wind; drift	From the south or southeast.
Suggested site	None suggested; country covered with forests.

94.—SCHRIEVER, LA.

Latitude	29° 45′.
Longitude	90° 48′
Altitude	16 feet.
Population	500.
Accommodations	One hotel.
Railroads	Southern Pacific, Thibodeaux and Houma Branch.
Topography	Bayou La Fourche 3 miles east; Bayou Terre Bonne passes through the town.
Eastern horizon	Misty.
Wind; drift	From the south.
Suggested site	None mentioned.

TABLE VI.—*Railroad abbreviations.*

C. & O	Chesapeake and Ohio.
N. & W	Norfolk and Western.
N. Y. P. & N	New York, Philadelphia, and Norfolk.
S. A. L	Seaboard Air Line.
A. C. L	Atlantic Coast Line.
Southern	Southern.
N. & C	Norfolk and Carolina.
N. & S	Norfolk and Southern
A. & D	Atlantic and Danville.
Va. B. & S	Virginia Beach and Southern.
A. & A	Aberdeen and Ashboro.
O. C	Ohio Central Lines.
C. & W. C	Charleston and Western Carolina.
Ga	Georgia.
Cent. of Ga	Central of Georgia.
A. & F	Alabama and Florida.
Ga. M	Georgia Midland.
M. & G	Mobile and Gerard.
S. A	Southern Alabama.
L. & N	Louisville and Nashville.
M. & B	Mobile and Birmingham.
M. & O	Mobile and Ohio.
M. J. & K. C	Mobile, Jackson, and Kansas City.
I. C	Illinois Central.
N. O. & N. E	New Orleans and Northeastern.
S. P	Southern Pacific.

This data is self-explanatory and needs no comment. The United States Coast and Geodetic Survey and the United States Geological Survey courteously furnished the values for latitude, longitude, and elevation for several places, as indicated in the collection. In all other cases the positions were scaled from the Rand, McNally & Co.'s large atlas for 1899.

Table VI gives the railroad titles in full. The preceding data contain all the facts which it has been practicable to secure, previous to a visit to the observing station, and before the actual occurrence of the eclipse itself, and it is offered to astronomers and amateur observers for their information. It might have been thought by some desirable to furnish other general meteorological data giving the pressure, temperature, and humidity, for places in the Southern States. This can yet be done if there is reason to believe astronomers can make any definite use of it. Our records for the region are very complete and are published quite fully in the annual reports of the Chief of the Weather Bureau, including the year 1897; also in the Monthly Weather Review up to date. By referring to them all the information needed can, doubtless, be found without further publication.

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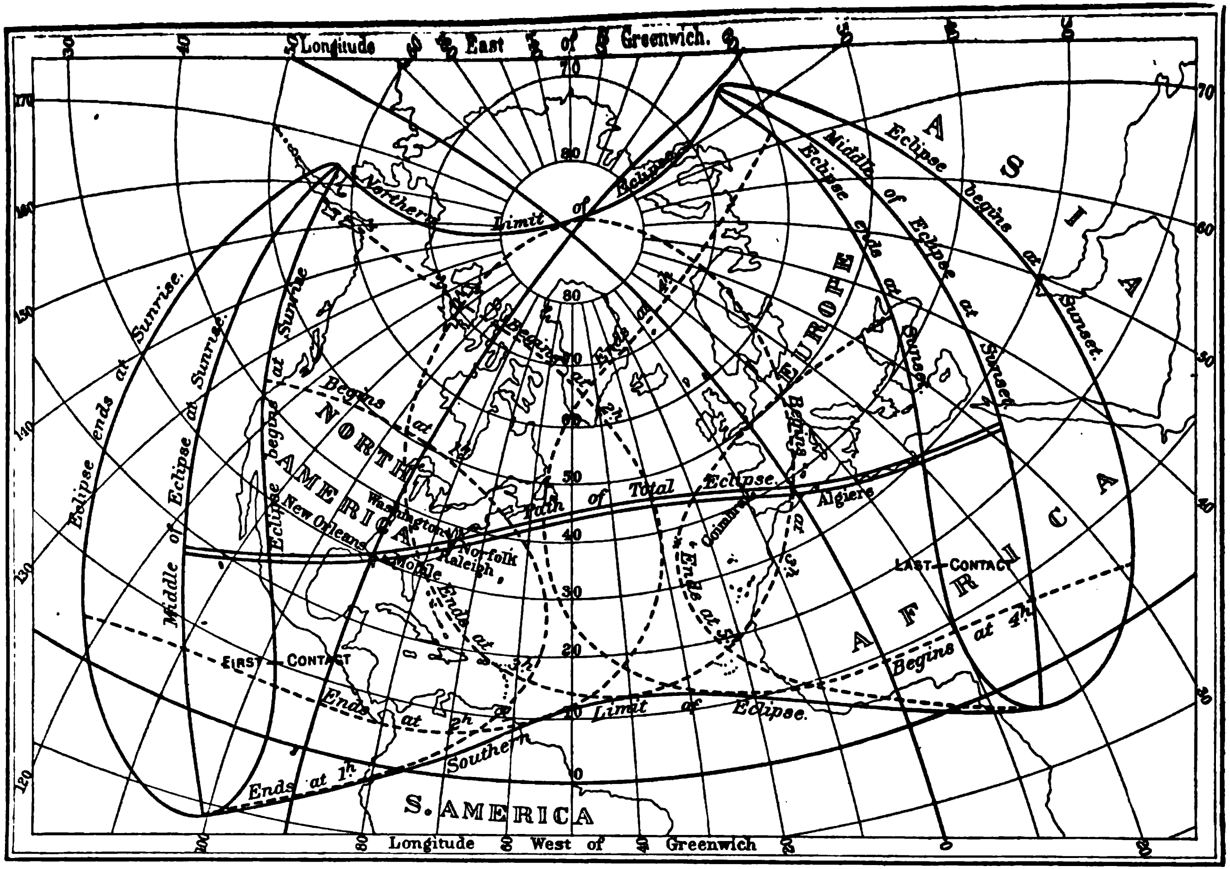
Chart I. Total Eclipse of May 28, 1900. From the American Ephemeris and Nautical Almanac.



Note.—The hours of beginning and ending are expressed in Greenwich mean time.

Chart II. Cloudiness in Path of Total Eclipse of May 28, 1900. Observations of 1899.

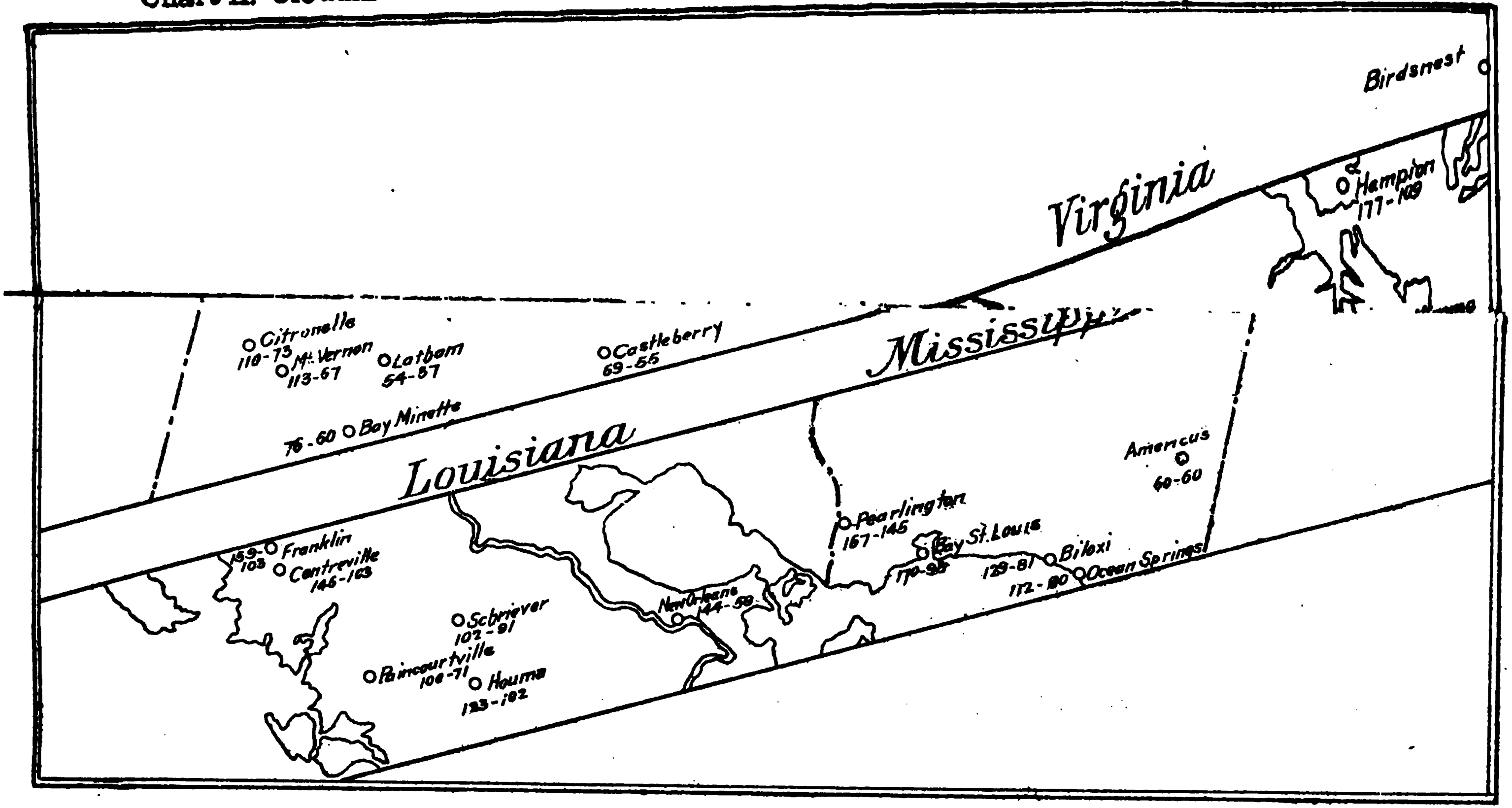
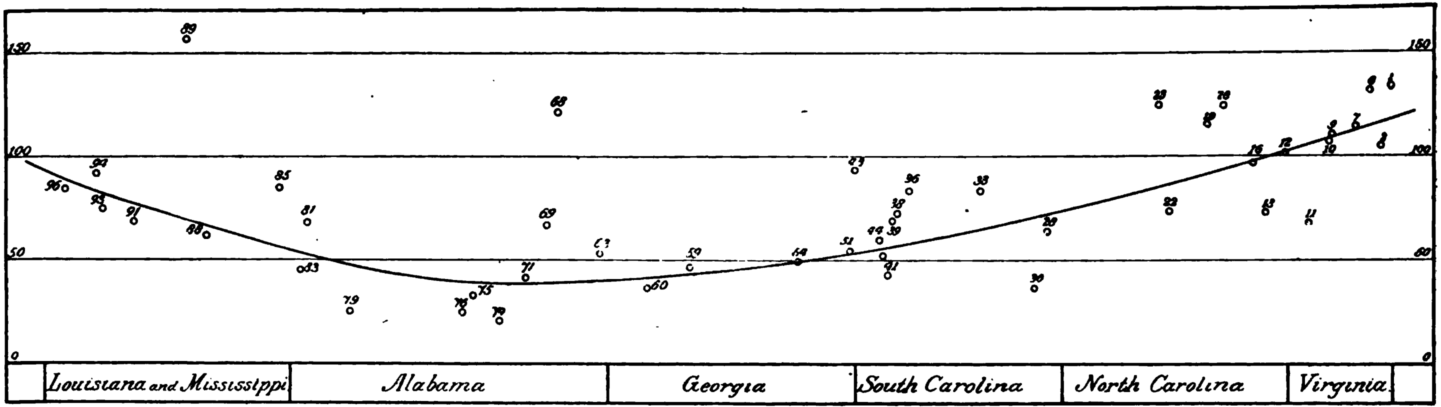
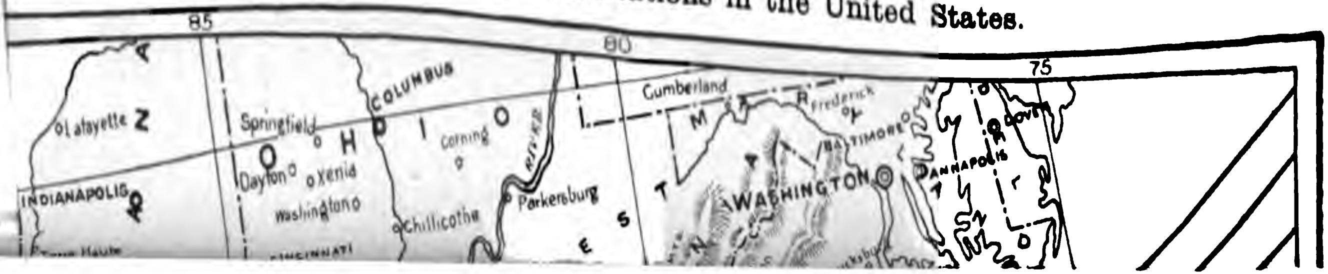


Chart III. Relative Average Cloudiness Along the Eclipse Track.



IV. The Eclipse Track and Observing Stations in the United States.



BULLETIN NO. 28.—W. B. No. 211. PRICE 15 CENTS.

U. S. DEPARTMENT OF AGRICULTURE.

WEATHER BUREAU.

THE
CLIMATE OF SAN FRANCISCO, CALIFORNIA.

Prepared under direction of
WILLIS L. MOORE,
Chief United States Weather Bureau,

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Weather Bureau,
Washington, D. C., November 11, 1899.

Hon. James Wilson,
Secretary of Agriculture.

Sir: I have the honor to submit herewith the manuscript of a paper entitled, "The Climate of San Francisco, Cal.," by Alexander G. McAdie, forecast official, and George H. Willson, local forecast official, and to recommend its publication as a bulletin of the Weather Bureau.

The climatic characteristics of the Pacific coast and the peculiar local environment of San Francisco combine to make a report of this character both interesting and instructive. The authors have presented the climatological data accumulated at the San Francisco station during the last thirty years in considerable detail, yet not more so than is warranted by the lack of such information and the relative importance of San Francisco as an objective point for many of our citizens who visit the Pacific coast.

Very respectfully,
Willis L. Moore,
Chief United States Weather Bureau.

Approved:
James Wilson, *Secretary.*

THE CLIMATE OF SAN FRANCISCO.

The city of San Francisco is justly famed for its peculiar climate. To a large degree the topography of a section controls its climate, and it is not surprising, therefore, to find that in the vicinity of San Francisco the topography is exceedingly diversified.

From the Weather Bureau station on Mount Tamalpais—elevation of station, 2,373 feet[1]—one looks down to the west on the broad expanse of the Pacific. From the open roadstead of Drakes Bay the eye passes over the Sausalito Hills to the headlands at Points Bonita and Lobos, marking the entrance to the Golden Gate. This passage plays an important rôle in connection with the winds, temperature, and fogs of the San Francisco Bay region. At mean tide the area of San Francisco Bay is about 450 square miles.

Far on the eastern horizon, especially on clear winter days, the snows of the Sierras, 155 miles distant, can be seen glistening. These mountains vary in height from 8,000 to 14,000 feet.

Extending from the slopes of the Sierras to the Coast Range is a great basin, 500 miles long and about 50 wide. The Sacramento and the San Joaquin rivers flowing through this basin unite in Suisun Bay. This great inland basin, surrounded by mountain walls, is connected with the Pacific Ocean by the Gate at San Francisco, San Francisco Bay, San Pablo Bay, Carquinez Straits, and Suisun Bay.

If a native of San Francisco were asked which was the coldest month of the year, he might be unable to answer, and if asked which was the warmest he might say November. This confusion arises from the comparatively small range of temperature. The mean annual temperature, as determined from the records of the Weather Bureau for 28 years, is 56.2°. May and November have practically the same temperature. The warmest month is September, 60.9°; the coldest January, 50.1°; the other months have mean temperatures as follows: February, 52°; March, 54°; April, 55°; May, 57°; June, 59°; August, 59°; October, 60°; November, 56°; December, 52°.

The highest temperature ever recorded in San Francisco was 100° on June 29, 1891, and the lowest 29° on January 15, 1888. Abnormally warm and cold periods last, as a rule, about three days. The mean of the three consecutive warmest days at San Francisco has never exceeded

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[1] West Peak, 2,604; Middle Peak, 2,520; East Peak, 2,592; latitude, 37° 56″ N.; longitude, 122° 36″ W.

76.3°. A period of warm weather during the summer months is, as a rule, brought to a close about the evening of the third day with strong west winds, dense fog, and temperatures ranging from 49° to 54°. The mean of the three consecutive coldest days was 40.7°. The greatest daily range of temperature was 43° on June 29, 1891. This was the date when the temperature reached 100°. The range of temperature was from 100° to 57°. The morning was calm and very warm while at 5 p. m. the temperature was 80° and next morning 74°.

Since the establishment of the Weather Bureau on Mount Tamalpais it has been evident that the conditions at San Francisco are those of sea level, while very different and more normal conditions prevail at elevations of several thousand feet. Thus, the mean monthly temperatures of San Francisco and Mount Tamalpais show that the seasonal changes are masked at the lower station while plainly marked at the upper:

1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Mount Tamalpais.	40.8	46.4	46.6	56.0	50.5	61.9	70.0	67.5	62.6	59.4	51.2	45.7	54.9
San Francisco.....	46.7	52.6	51.2	54.5	52.6	59.0	56.0	58.0	59.0	61.2	55.4	49.7	54.7

The difference in temperature on summer days is often very great. During the month of June, 1899, an attempt was made to use this vertical thermal gradient in practical forecasting. It would perhaps be more accurate to describe this difference as a thermal decrement, since it is largely a cooling due to the proximity of the Pacific with its 16,000,000 square miles of water, the mean temperature of the ocean water along the northern coast of California averaging 55°.

Including every day in the month of June there was found to be a mean daily difference of 11.4°, or, in other words, from the data obtained by means of this mountain station, checked by data from Point Reyes and Mount Hamilton, the temperature rose at the rate of 1° for every 203 feet of elevation. This increase held at least up to 2,380 feet.

If we consider only those days in the month (24) when there was a rise with elevation, we have for the mean daily difference in temperature between Mount Tamalpais and San Francisco 15.3°; i. e., the temperature rises 1° for every 155 feet elevation. This may be adopted as a working normal summer-day gradient.

For days when there was a decrease in temperature with elevation, 6 in all, we find a difference of 5.9°, or there was 1° fall for every 402 feet, which it may be noted is not quite as steep a gradient as values generally given in text-books—1° for every 300 feet.

We notice first that periods of rainy or cloudy and cold weather occur when the surface temperatures are higher than those of the upper level. It would seem as if at these times the different air strata from sea level to 2,500 feet had been intermingled to some degree, and the cold layer usually existing close to the surface had been temporarily displaced.

Fogs seem to occur at times of steep inverted gradients; in other words, when the temperature of the 2,500-foot level is considerably higher than at sea level.

The summer fogs of San Francisco result from a chilling of the upper warm air, descending to the ocean surface, and particularly over the cold current close to the shore. There is a great difference of temperature between the valley and the ocean, often 50° within as many miles, and this is probably the prime factor in establishing a marked air movement, shown by the strong indraft through the Gate on summer afternoons (see charts of hourly wind velocity, 3 to 7 p. m.).

An interesting instance of the effect of fog in lowering the temperature occurred on July 25, 1899. At Mount Tamalpais at about 4 a. m. the temperature was 64°; at 5 a. m. the fog rose until it reached a height of 2,200 feet and the temperature fell to 47°. The temperature at San Francisco at the same hour was 54°.

Passing from the fogs of the summer months, the seasonal character of the rainfall demands attention. Referring to the tables and charts accompanying, it will be seen that July and August are practically without rain, while December and January together have nearly 10 inches. The annual rainfall is 23 inches.

By comparing the seasonal rainfall with the crop yield it would appear that in years when the rain falls generously in March and April the yield is largest, other things being equal. In other words, it is the time distribution of the rain, more than the intensity or total rainfall, which benefits vegetation.

The Weather Bureau (Signal Service) office was originally located in the Merchants' Exchange Building, and the first observation taken February 2, 1871. The office was moved to the Phelan Building September 4, 1890. On November 1, 1892, it was moved to its present quarters in the Mills Building.

The present elevations of instruments above the ground are, thermometers 161 feet, rain gauge 154 feet.

Monthly mean temperatures.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1871	....	....	51.3	53.3	54.3	56.9	56.6	57.9	60.4	61.8	55.1	52.9	56.0
1872	52.2	54.2	54.3	53.4	56.0	59.8	57.9	59.8	59.3	58.8	56.0	52.1	56.2
1873	54.8	50.9	54.5	54.6	55.4	57.1	58.1	59.5	58.3	59.7	57.7	50.7	55.9
1874	49.3	51.2	50.9	54.9	57.6	59.1	57.8	59.0	61.4	59.8	56.1	50.3	55.6
1875	49.0	52.0	51.8	55.4	57.2	59.4	58.8	58.8	59.2	62.0	57.4	51.4	56.0
1876	48.8	52.8	53.2	55.4	56.8	61.4	59.1	59.6	61.5	59.9	58.0	53.0	56.6
1877	54.3	55.8	57.2	54.4	56.2	62.0	60.8	59.8	62.5	59.2	57.2	52.7	57.7
1878	52.8	53.3	55.9	56.0	58.0	58.8	58.6	59.1	60.2	61.6	57.1	51.6	56.9
1879	48.8	54.6	57.2	56.5	56.4	60.2	58.7	60.5	61.0	61.0	55.0	50.0	56.7
1880	48.0	48.8	49.4	53.3	57.7	57.2	58.8	59.1	58.9	59.8	54.2	53.2	54.9
1881	54.0	55.3	54.4	57.9	58.0	58.6	59.7	58.8	59.7	56.6	55.1	51.0	56.6
1882	49.4	48.8	53.4	53.0	57.0	57.9	59.5	58.6	59.8	58.8	53.2	52.8	55.2
1883	47.0	48.8	54.0	53.2	58.0	61.4	59.8	59.2	63.1	57.9	54.1	50.8	55.6
1884	50.6	50.8	54.5	56.0	59.4	60.2	61.4	60.0	59.6	58.2	57.4	52.8	56.7
1885	51.1	55.3	57.7	58.2	58.1	57.8	61.6	59.6	61.8	60.7	57.8	54.0	57.8
1886	51.2	56.8	53.6	55.4	59.1	59.4	60.3	60.6	62.4	58.6	56.8	53.6	57.3
1887	52.6	47.8	55.8	55.8	57.0	59.4	56.6	57.8	62.0	64.2	56.4	52.2	56.5
1888	46.7	53.9	53.4	57.8	56.9	62.4	61.4	60.8	62.6	61.6	57.0	53.2	57.3
1889	50.4	54.0	57.2	58.8	58.8	60.2	58.8	60.4	64.6	61.8	58.6	51.3	57.9
1890	46.2	49.1	53.8	54.8	59.8	59.2	59.8	61.4	60.4	62.4	59.0	49.8	56.3
1891	52.2	51.1	55.0	53.4	55.7	60.2	59.4	61.8	61.8	59.7	58.6	49.6	56.6
1892	51.7	52.4	54.2	53.1	58.0	56.8	58.1	59.4	60.2	59.6	56.9	51.1	56.0
1893	47.4	50.3	51.2	52.4	55.8	56.5	56.6	56.6	59.3	57.6	55.6	52.4	54.3
1894	47.7	48.4	50.6	55.2	55.4	55.9	56.4	59.2	63.4	59.6	59.4	49.7	55.1
1895	48.6	53.8	52.2	54.8	57.6	58.7	58.4	58.4	60.7	58.8	56.2	48.6	55.6
1896	52.2	55.3	54.3	51.6	56.3	57.2	59.4	59.5	59.6	58.8	53.4	52.8	55.9
1897	48.6	50.7	48.9	57.4	57.4	58.9	58.2	57.4	60.8	58.4	53.1	50.7	55.0
1898	46.7	52.6	51.2	54.4	52.6	59.0	56.2	57.0	59.0	61.2	55.4	49.7	54.6
Sums	1352.3	1408.8	1501.1	1540.4	1596.5	1651.6	1646.8	1659.6	1703.5	1678.1	1577.8	1444.0	1572.8
Means	50.1	52.2	53.6	55.0	57.0	59.0	58.8	59.3	60.9	59.9	56.4	51.6	56.2

SUMMARY OF MONTHLY MEAN TEMPERATURES.

Highest monthly mean	date	1873	1886	1885	1889	1890	1888	1885	1891	1889	1887	1894	1885	1889
		54.8	56.8	57.7	58.8	59.8	62.4	61.6	61.8	64.6	64.2	59.4	54.0	57.9
Lowest monthly mean	date	1890	1887	1897	1891	1898	1894	1898	1893	1873	1881	1897	1895	1893
		46.2	47.8	48.9	51.6	52.6	55.9	56.2	56.6	58.3	56.6	53.1	48.6	54.3
Absolute maximum	date	26, 1890	18, 1899	7, 1892	14, 1888	28, 1887	29, 1891	15, 1888	22, 1891	22, 1894	8, 1899	16, 1895	8, 1893	[1] 1891
		78	80	80	88	97	100	93	92	94	94	83	72	100

Absolute minimum { date	15, 1888	5, 1887	3, 1896	7, 1891	16, 1894	19, 1893	31, 1893	8, 1893	30, 1894	14, 1881	27, 1896	24, 1879	[2] 1888
Absolute minimum {	29	33	33	40	44	47	47	47	40	45	38	34	29
Greatest daily range	24	27	28	34	39	43	36	38	35	31	25	20	43
Mean daily range	9.9	10.7	11.3	11.7	12.0	12.5	11.5	11.4	13.3	13.3	11.3	9.3	11.5
Mean variability	2.2	2.0	2.5	2.7	2.9	2.4	2.4	2.4	3.0	3.5	2.6	2.2	2.6
Mean of three consecutive warmest days[3]	67.0	64.7	67.7	66.7	73.7	76.0	66.3	76.0	76.3	71.7	69.3	62.0	76.3
Mean of three consecutive coldest days[3]	42.7	43.7	40.7	48.3	49.7	53.0	50.0	52.7	54.0	52.0	44.7	42.3	40.7

WEATHER.

Average number clear days	11	10	11	12	13	14	11	10	14	16	15	12	149
Average number partly cloudy days	10	10	11	12	12	11	14	15	12	11	9	10	137
Average number cloudy days	10	8	9	6	6	5	6	6	4	4	6	9	79
Average number rainy days	11	10	10	7	4	2	1	[4] 0	2	4	7	11	69

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[1] June 29.

[2] January 15.

[3] Record subsequent to January 1, 1891.

[4] Only 10 days in 27 years.

Monthly precipitation (in inches and hundredths).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	Season of—	Seasonal.
1849	....	....	....	....	....	....	0.00	0.00	0.00	8.14	8.66	6.20	....	....	....
1850	8.34	1.77	4.53	0.46	0.00	0.00	0.00	0.00	0.33	0.00	0.92	1.05	17.40	1849–50	38.10
1851	0.72	0.54	1.94	1.23	0.67	0.00	0.00	0.00	1.03	0.21	2.12	7.10	15.56	1850–51	7.40
1852	0.58	0.14	6.68	0.26	0.32	0.00	0.00	0.00	0.00	0.80	5.31	13.20	27.29	1851–52	18.44
1853	3.92	1.42	4.86	5.37	0.35	0.00	0.00	0.04	0.46	0.12	2.28	2.32	21.14	1852–53	35.23
1854	3.88	8.04	3.51	3.12	0.02	0.08	0.00	0.01	0.15	2.41	0.34	0.81	22.37	1853–54	23.87
1855	3.67	4.77	4.64	5.00	1.88	0.00	0.00	0.00	0.00	0.00	0.67	5.76	26.39	1854–55	23.68
1856	9.40	0.50	1.60	2.94	0.76	0.03	0.02	0.00	0.07	0.45	2.79	3.75	22.31	1855–56	21.66
1857	2.45	8.59	1.62	0.00	0.02	0.12	0.00	0.05	0.00	0.93	3.01	4.14	20.93	1856–57	19.88
1858	4.36	1.83	5.55	1.55	0.34	0.05	0.05	0.16	0.00	2.74	0.69	6.14	23.46	1857–58	21.81
1859	1.28	6.32	3.02	0.27	1.55	0.00	0.00	0.02	0.03	0.05	7.28	1.57	21.39	1858–59	22.22
1860	1.64	1.60	3.99	3.14	2.86	0.09	0.21	0.00	0.00	0.19	0.58	6.16	20.46	1859–60	22.27
1861	2.47	3.72	4.08	0 51	1.00	0.08	0.00	0.00	0.02	0.00	4.10	9.54	25.52	1860–61	19.00
1862	24.36	7.53	2.20	0.73	0.74	0.05	0.00	0.00	0.00	0.40	0.15	2.35	38.51	1861–62	49.27
1863	3.63	3.19	2.06	1.04	0.26	0.00	0.00	0.00	0.03	0.00	2.55	1.80	14.56	1862–63	13.08
1864	1.83	0.00	1.52	1.57	0.78	0.00	0.00	0.21	0.01	0.13	6.68	8.91	21.64	1863–64	10.08
1865	5.14	1.34	0.74	0.94	0.63	0.00	0.00	0.00	0.24	0.26	4.19	0.58	14.06	1864–65	24.73
1866	10.88	2.12	3.04	0.12	1.46	0.04	0.00	0.00	0.11	0.00	3.35	15.16	36.28	1865–66	22.93
1867	5.16	7.20	1.58	2.36	0.00	0.00	0.00	0.00	0.04	0.20	3.41	10.69	30.64	1866–67	34.92
1868	9.50	6.13	6.30	2.31	0.03	0.23	0.00	0.00	0.00	0.15	1.18	4.34	30.17	1867–68	38.84
1869	6.35	3.90	3.14	2.19	0.08	0.02	0.00	0.00	0.12	1.29	1.19	4.31	22.59	1868–69	21.35
1870	3.89	4.78	2.00	1.53	0.20	0.00	0.00	0.00	0.03	0.00	0.43	3.38	16.24	1869–70	19.81
1871	3.07	3.76	[1] 1.05	1.89	0.23	0.01	0.00	0.02	0.00	0.07	2.81	14.36	20.44	1870–71	14.10
1872	4.00	6.90	1.59	0.81	0.18	0.04	0.01	0.00	0.04	0.11	2.79	5.95	22.42	1871–72	34.71
1873	1.58	3.94	0.79	0.43	0.00	0.02	0.01	0.08	0.00	0.83	1.16	9.72	18.56	1872–73	18.02
1874	5.66	2.21	3.36	0.90	0.66	0.14	0.00	0.00	0.02	2.69	6.55	0.33	22.52	1873–74	23.98
1875	8.01	0.32	1.30	0.10	0.22	1.02	0.00	0.00	0.00	0.24	7.27	4.15	22.63	1874–75	18.40
1876	7.55	4.92	5.49	1.29	0.24	0.04	0.01	0.01	0.38	3.36	0.25	0.00	23.54	1875–76	26.01
1877	4.32	1.18	1.08	0.26	0.18	0.01	0.02	0.00	0.00	0.65	1.57	2.66	11.93	1876–77	11.04
1878	11.97	12.52	4.56	1.06	0.16	0.01	0.01	Trace.	0.55	1.27	0.57	0.58	33.26	1877–78	35.18
1879	3.52	4.90	8.75	1.89	2.35	0.05	0.01	0.02	Trace.	0.78	4.03	4.46	30.76	1878–79	24.44
1880	2.23	1.87	2.08	10.06	1.12	0.00	0.00	0.00	0.00	0.05	0.33	12.33	30.07	1879–80	26.66
1881	8.69	4.65	0.90	2.00	0.22	0.69	0.00	0.00	0.25	0.54	1.94	3.85	23.73	1880–81	29.86
1882	1.68	2.96	3.45	1.22	0.21	0.04	0.00	0.00	0.26	2.66	4.18	2.01	18.67	1881–82	16.14
1883	1.92	1.04	3.01	1.51	3.52	0.01	0.00	0.00	0.42	1.48	1.60	0.92	15.43	1882–83	20.12
1884	3.94	6.65	8.24	6.33	0.23	2.57	Trace.	0.04	0.33	2.55	0.26	7.68	38.82	1883–84	32.38
1885	2.53	0.30	1.01	3.17	0.04	0.19	0.06	Trace.	0.11	0.72	11.78	4.99	24.90	1884–85	18.10
1886	7.42	0.24	2.07	5.28	0.37	0.01	0.23	Trace.	0.01	1.48	0.84	2.07	20.02	1885–86	33.05
1887	1.90	9.24	0.84	2.30	0.06	0.07	Trace.	0.01	0.29	Trace.	0.99	3.34	19.04	1886–87	19.04
1888	6.81	0.94	3.60	0.11	0.38	0.27	0.01	0.01	0.98	0.13	3.99	5.80	23.03	1887–88	16.74
1889	1.28	0.72	7.78	0.96	2.17	0.03	0.01	Trace.	Trace.	7.28	2.90	13.81	36.94	1888–89	23.86
1890	9.61	5.16	4.73	1.18	1.07	0.10	0.02	0.00	0.31	0.00	0.00	3.25	25.43	1889–90	45.85
1891	0.98	7.26	1.96	2.44	1.25	0.11	0.10	0.02	0.77	0.04	0.56	5.62	21.11	1890–91	17.58

1892	2.42	2.90	2.85	1.39	1.86	Trace.	0.00	0.00	0.02	1.65	3.91	5.08	22.08	1891-92	18.58
1893	3.05	2.75	4.08	1.03	0.15	0.03	0.02	0.00	0.21	0.16	4.18	2.25	17.91	1892-93	22.05
1894	5.99	2.69	0.60	0.50	1.31	0.56	Trace.	0.00	1.05	1.73	0.88	9.01	24.32	1893-94	18.47
1895	6.99	2.31	1.89	1.24	0.60	0.00	0.01	0.00	0.77	0.11	1.78	1.48	17.13	1894-95	27.29
1896	8.14	0.28	2.85	5.16	0.72	0.00	0.04	0.09	0.52	1.55	4.56	4.34	28.25	1895-96	21.25
1897	2.26	4.41	4.56	0.27	0.61	0.22	Trace.	Trace.	0.10	1.70	1.05	1.22	16.40	1896-97	23.48
1898	1.12	2.13	0.24	0.19	1.44	0.19	0.00	Trace.	1.06	0.86	0.46	1.62	9.31	1897-98	9.88
1899	3.67	0.10	7.61	0.62	0.86	0.01	0.00	Trace.	0.00	3.92	3.79	2.65	23.23	1898-99	16.87
Sums	245.76	174.68	160.92	92.23	36.86	7.23	0.89	0.79	11.12	52.08	138.86	254.74	1150.79	....	....
Means	4.92	3.49	3.22	1.84	0.73	0.14	0.02	0.02	0.22	1.02	2.72	4.99	23.02	....	....

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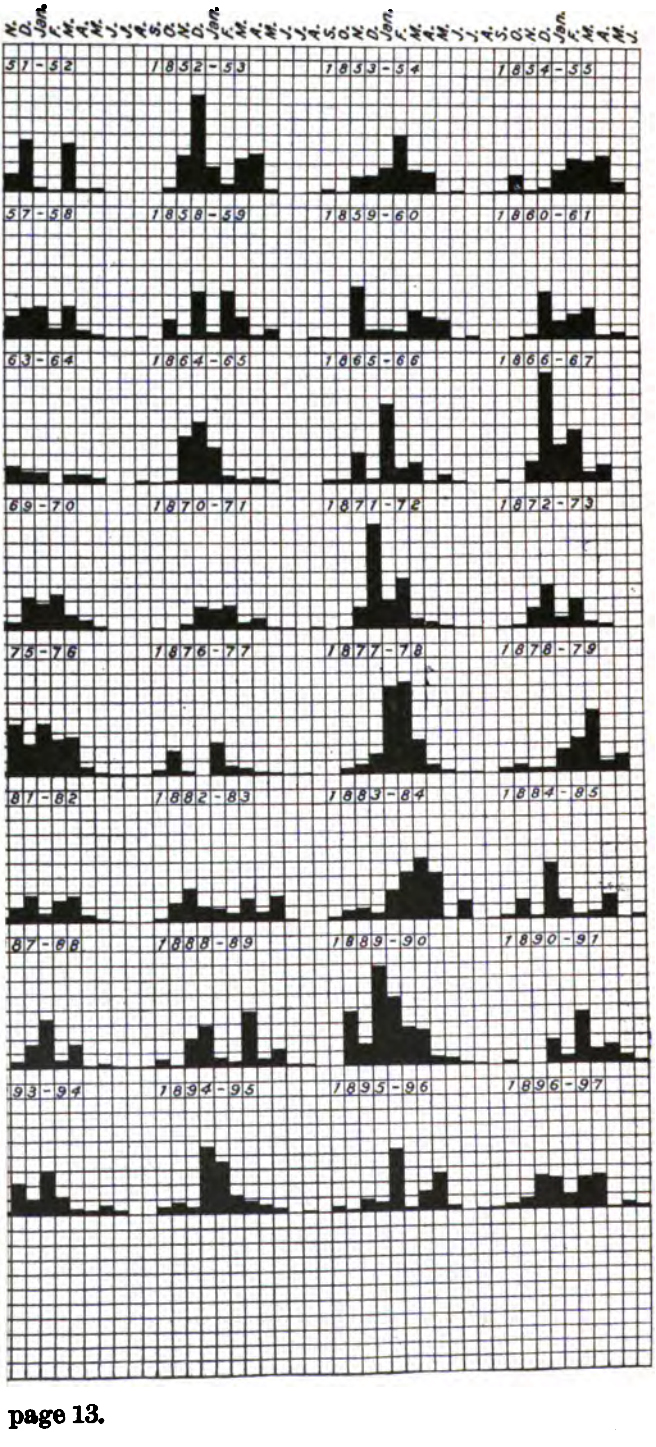
[1] Beginning of Weather Bureau record.

Greatest precipitation in twenty-four hours for each month.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Greatest annual.
1871	....	....	0.57	1.28	0.13	0.01	0.00	0.02	0.00	0.07	1.24	3.14	3.14
1872	2.36	1.28	0.73	0.35	0.15	0.03	0.01	0.00	0.04	0.11	2.06	2.33	2.36
1873	1.02	0.82	0.54	0.36	0.00	0.01	0.01	0.05	0.00	0.77	0.80	2.33	2.33
1874	1.61	0.81	0.65	0.70	0.23	0.13	0.00	0.00	0.02	1.58	3.98	0.15	3.98
1875	2.19	0.27	0.45	0.06	0.14	0.90	0.00	0.00	0.00	0.22	2.37	1.50	2.37
1876	1.76	1.80	1.59	0.60	0.24	0.04	0.01	0.01	0.20	1.39	0.19	0.00	1.80
1877	1.63	0.52	0.56	0.08	0.18	0.01	0.02	0.00	0.00	0.36	0.56	1.11	1.63
1878	1.98	1.92	1.01	0.61	0.14	0.01	0.01	Trace.	0.45	1.27	0.45	0.33	1.98
1879	1.04	1.66	3.31	0.72	0.93	0.05	0.01	0.02	Trace.	0.56	1.38	1.55	3.31
1880	1.03	0.64	0.57	2.21	0.84	0.00	0.00	0.00	0.00	0.05	0.32	2.36	2.36
1881	4.67	1.37	0.69	1.09	0.17	0.41	0.00	0.00	0·25	0.21	1.34	1.35	4.67
1882	0.57	0.82	0.86	0.44	0.15	0.02	0.00	0.00	0.26	1.40	2.41	0.76	2.41
1883	1.30	0.71	1.63	0.76	1.23	0.01	0.00	0.00	0.42	1.19	1.01	0.28	1.63
1884	1.44	1.52	2.21	1.66	0.12	1.23	0.00	0.03	0.21	1.15	0.19	2.07	2.21
1885	0.97	0.15	0.55	2.03	0.04	0.10	0.05	Trace.	0.11	0.70	2.58	2.78	2.78
1886	2.40	0.18	0.65	1.36	0.21	0.01	0.23	0.00	0.01	0.72	0.77	1.10	2.40
1887	0.80	3.60	0.52	1.45	0.03	0.07	Trace.	0.01	0.18	0.00	0.48	1.14	3.60
1888	1.58	0.38	1.34	0.11	0.19	0.10	0.01	0.01	0.92	0.05	1.68	1.51	1.68
1889	0.81	0.59	3.08	0.30	1.29	0.03	0.01	Trace.	Trace.	2.03	0.92	1.46	3.08
1890	2.08	1.63	1.86	0.55	0.53	0.05	0.02	0.00	0.31	0.00	0.00	1.90	2.08
1891	0.75	3.38	0.68	1.20	0.61	0.10	0.04	0.02	0.63	0.03	0.26	2.21	3.38
1892	1.06	1.03	0.90	0.38	1.15	Trace.	0.00	0.00	0.02	0.91	1.46	2.34	2.34
1893	1.39	1.06	0.98	0.71	0.14	0.03	0.02	0.00	0.12	0.10	1.69	0.97	1.69
1894	2.61	1.05	0.84	0.30	0.68	0.22	Trace.	0.00	1.04	0.64	0.88	1.64	2.61
1895	1.96	1.44	0.67	0.89	0.27	0.00	0.01	0.00	0.62	0.06	1.06	0.51	1.96
1896	1.85	0.18	0.84	2.43	0.34	0.00	0.04	0.06	0.41	1.46	2.79	1.65	2.79
1897	1.08	1.23	1.42	0.20	0.61	0.19	Trace.	Trace.	0.08	1.41	0.42	1.02	1.42
1898	0.33	0.78	0.13	0.19	1.23	0.18	0.00	Trace.	0.73	0.45	0.36	0.70	1.23
1899	0.98	0.08	2.15	0.45	0.77	0.01	0.00	Trace.	0.00	1.94	1.51	1.17	2.15
Greatest	4.67	3.60	3.31	2.43	1.29	1.23	0.23	0.06	1.04	2.03	3.98	3.14	....
Greatest date	29, 1881	4–5, 1887	4–5, 1879	23–24, 1896	4–5, 1889	11–12, 1884	16, 1886	29–30, 1896	29–30, 1894	17–18, 1889	23, 1874	18–19, 1871	....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1896-97

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Dates when precipitation equaled or exceeded 2.50 inches in any consecutive twenty-four hours at San Francisco, Cal.

	Inches.
December 17 and 18, 1871, from 11.43 p. m. 17th to 11.43 p. m. 18th	2.83
December 18 and 19, 1871, from 11.43 p. m. 18th to 11.43 p. m. 19th	3.12
November 22 and 23, 1874, from 11.08 p. m. 22d to 11.08 p. m. 23d	3.98
March 4 and 5, 1879, from 4.43 p. m. 4th to 4.43 p. m. 5th	3.31
January 28 and 29, 1881, from 11.08 p. m. 28th to 11.08 p. m. 29th	4.67
November 23 and 24, 1885, from 11 p. m. 23d to 11 p. m. 24th	2.58
December 21, 1885, from 1.35 a. m. 21st to 1.35 p. m. 21st	2.78
February 4 and 5, 1887, from 3 p. m. 4th to 3 p. m. 5th	3.60
March 12 and 13, 1889, from 8.15 a. m. 12th to 8 a. m. 13th	3.08
February 14 and 15, 1891, from 8.45 p. m. 14th to 8 p. m. 15th	3.38
January 19 and 20, 1894, from 8 p. m. 19th to 8 p. m. 20th	2.61
November 23 and 24, 1896, 6 a. m. 23d to 6 a. m. 24th	2.79

Maximum rate of rainfall (record since 1893): Five minutes, 0.15; 10 minutes, 0.17; 1 hour, 0.55.

Greatest monthly precipitation and date.

Month.	Year.	Amount.	Month.	Year.	Amount.
January	1862	24.36	July	1886	0.23
February	1878	12.52	August	1864	0.21
March	1879	8.75	September	1898	1.06
April	1880	10.06	October	1889	7.28
May	1883	3.52	November	1885	11.78
June	1884	2.57	December	1866	15.16

Least monthly precipitation and date.

Month.	Year.	Amount.	Month.	Year.	Amount.
January	1852	0.58	July	(1)	0
February	1864	0	August	(1)	0
March	1898	0.24	September	(1)	0
April	1857	0	October	(1)	0
May	(1)	0	November	1890	0
June	(1)	0	December	1876	0

[1] Many years.

Number of times monthly precipitation has exceeded the normal for fifty years.

Month.	Total.	First 25 years.	Second 25 years.	Month.	Total.	First 25 years.	Second 25 years.
January	19	9	10	July	6	2	4
February	22	13	9	August	7	5	2
March	20	10	10	September	18	4	14
April	18	9	9	October	16	5	11
May	18	8	10	November	23	15	8
June	9	1	8	December	20	13	7

Total number of days on which precipitation has fallen since March 1, 1871.

Month.	Less than 0.01.	0.01–0.10.	0.11–0.25.	0.26–0.50.	0.51–1.00.	Over 1.00.
January	35	109	61	56	54	34
February	21	114	56	51	45	18
March	45	129	63	50	45	17
April	44	96	40	32	16	16
May	49	73	23	10	12	3
June	28	43	6	5	3	0
July	13	16	1	0	0	0
August	18	13	0	0	0	0
September	24	31	11	6	5	0
October	24	54	17	15	17	10
November	26	72	39	32	19	23
December	27	89	55	72	46	38

Foggy days and thunderstorms.

Month.	Total number of foggy days.	Number of thunderstorms.	Month.	Total number of foggy days.	Number of thunderstorms.
January	18	2	July	18	1
February	10	0	August	26	1
March	10	1	September	20	2
April	6	2	October	27	1
May	1	1	November	22	0
June	7	1	December	15	4

Record began January 1, 1891.

Number of high winds.

Month.	Velocity.			Month.	Velocity.		
	30 to 35.	36 to 40.	Over 40.		30 to 35.	36 to 40.	Over 40.
January	18	16	7	July	155	42	1
February	20	7	1	August	133	26	2
March	37	11	2	September	86	4	0
April	67	12	2	October	34	3	0
May	92	11	2	November	10	1	5
June	166	28	3	December	23	6	3

Record commencing September 1, 1881.

Highest wind velocity, direction, and date for each month.

Month.	Velocity.	Direction.	Date.	Month.	Velocity.	Direction.	Date.
January	48	SW.	26, 1875	July	41	W.	15, 1898
February	48	SW.	[1]22, 1891	August	42	SW.	2, 1893
March	44	N.	8, 1880	September	38	SW.	11, 1894
April	47	NW.	23, 1871	October	38	N.	29, 1877
May	45	W.	11, 1897	November	56	SE.	30, 1892
June	48	SW.	30, 1873	December	60	SE.	23, 1892

[1] Cups blew off before maximum was reached.

Average velocity of afternoon winds.

Month.	2 to 3.	3 to 4.	4 to 5.	Month.	2 to 3.	3 to 4.	4 to 5.
January	8.8	8.6	8.0	July	21.0	21.6	22.0
February	10.5	10.8	10.8	August	20.2	20.9	20.8
March	13.4	14.1	14.1	September	17.7	18.5	18.4
April	16.7	17.3	16.9	October	13.4	14.0	14.1
May	18.0	18.5	18.1	November	9.2	9.4	9.6
June	20.8	21.3	21.0	December	8.4	8.1	7.7

Average hourly velocity.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1 a. m	6.1	6.1	6.7	7.3	7.9	9.3	9.2	8.9	6.8	5.3	5.2	6.1
2 a. m	6.2	5.9	6.3	7.0	7.6	8.8	8.8	8.5	6.4	5.0	5.1	6.2
3 a. m	6.3	5.8	6.3	6.6	7.2	8.2	8.2	7.9	6.0	4.9	5.2	6.2
4 a. m	6.3	5.9	6.2	6.3	6.8	7.6	7.8	7.6	5.9	4.8	5.1	6.3
5 a. m.	6.4	6.1	6.3	6.1	6.6	7.1	7.4	7.3	5.6	4.8	5.2	6.4
6 a. m	6.5	5.9	6.1	6.0	6.4	6.9	7.4	6.9	5.4	4.7	5.3	6.5
7 a. m	6.4	5.8	6.1	6.2	6.7	7.1	7.4	6.8	5.4	4.7	5.1	6.6
8 a. m	6.5	6.2	6.6	7.0	7.5	8.1	8.0	7.4	5.8	5.0	5.5	6.8
9 a. m	7.0	6.9	7.8	7.8	8.3	8.8	8.6	7.8	6.4	5.6	6.1	7.1
10 a. m	7.6	7.6	8.0	8.6	9.3	10.3	9.9	8.9	7.0	6.2	6.6	7.7
11 a. m	7.9	7.6	8.4	9.7	11.0	12.4	11.8	11.1	8.3	6.7	6.7	7.8
12 noon	8.2	7.8	9.2	11.6	13.3	15.2	14.7	13.3	10.7	8.1	6.8	7.9
1 p. m	8.4	8.6	10.6	13.9	15.4	17.8	17.4	16.0	13.3	9.9	7.4	8.2
2 p. m	8.7	9.6	12.2	15.6	17.0	19.8	19.7	18.5	15.7	11.8	8.6	8.5
3 p. m	8.8	10.5	13.4	16.7	18.0	20.8	21.0	20.2	17.7	13.4	9.2	8.4
4 p. m	8.6	10.8	14.1	17.3	18.5	21.3	21.6	20.9	18.5	14.0	9.4	8.1
5 p. m	8.0	10.8	14.1	16.9	18.1	21.0	22.0	20.8	18.4	14.1	9.6	7.7
6 p. m	7.6	9.8	13.1	15.9	17.1	20.1	20.7	19.9	17.0	13.2	8.8	7.6
7 p. m	7.3	9.0	11.6	14.3	15.2	18.2	18.7	17.5	14.8	11.0	7.7	7.0
8 p. m	6.8	8.3	9.9	12.3	13.1	16.1	16.2	15.2	12.0	9.0	6.7	6.7
9 p. m	6.5	7.4	8.6	10.6	11.3	13.5	14.0	13.3	10.0	7.7	6.1	6.6
10 p. m	6.1	7.0	7.8	9.5	10.0	11.8	12.3	11.3	9.0	6.6	5.6	6.4
11 p. m	5.9	6.4	7.2	8.6	9.0	10.8	10.8	10.2	8.2	6.0	5.2	6.2
12 midnight	6.0	6.1	6.8	7.8	8.3	10.1	10.0	9.4	7.4	5.6	5.1	6.0
Average	7.0	7.6	8.8	10.4	11.3	13.0	13.1	12.8	10.1	7.8	6.6	7.0

Monthly relative humidity.

Month.	A. M.	P. M.	Average.	Month.	A. M.	P. M.	Average.
	Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
January	83	75	79	July	89	80	84
February	83	73	78	August	90	82	86
March	82	73	78	September	88	78	83
April	83	74	78	October	85	74	80
May	84	74	79	November	82	71	76
June	86	75	80	December	84	76	80

Dates of snowfall in San Francisco since March 1, 1871.

January 21, 1876.—Light snow fell for 10 minutes.

December 31, 1882.—Heavy snow fell from 11.30 a. m. to 4.20 p. m.; amount, 3.5 inches.

February 6, 1883.—A few flakes of snow fell during the day.

February 7, 1884.—Snow fell at intervals during the day, depth varying from 1 to 2 inches.

February 5, 1887.—Snow fell during the day; depth at office 3.7 inches, while in the western portion of the city it was fully 7 inches deep.

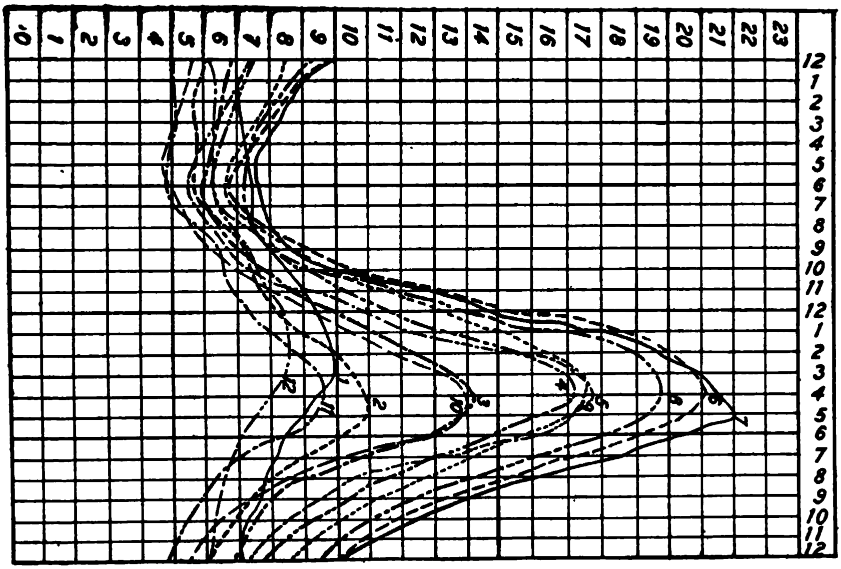
January 4, 1888.—A few flakes of snow fell during the day.

January 16, 1888.—Light snow fell to the depth of 0.1 inch.

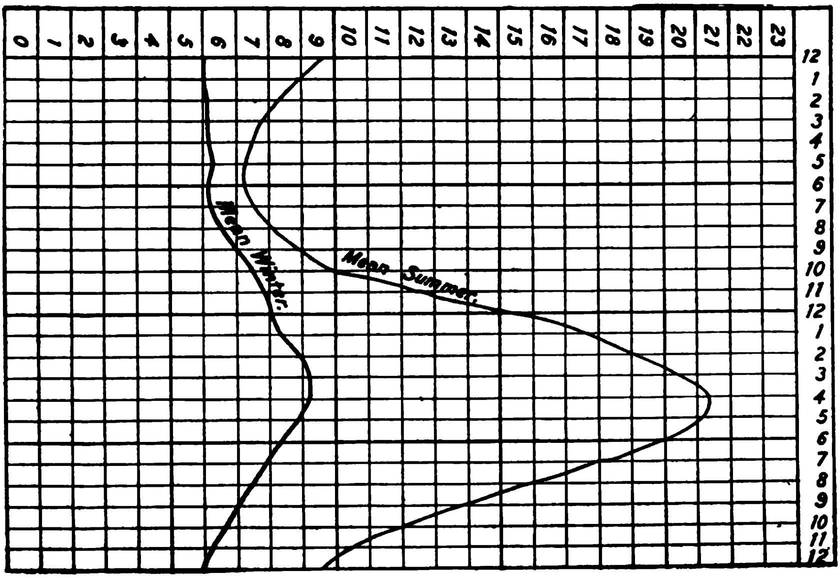
March 2, 1894.—A few flakes of snow fell during the day.

March 2, 1896.—Snow mixed with rain fell at intervals during the day.

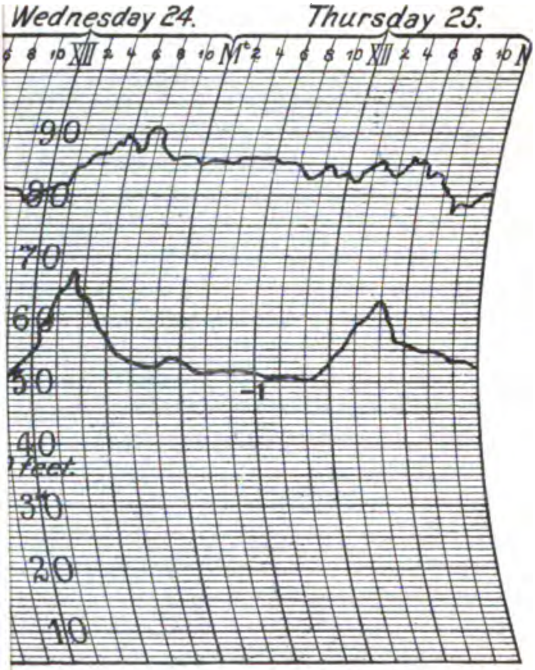
March 3, 1896.—Heavy snow fell during the night; depth at office at 8 a. m., 1 inch.



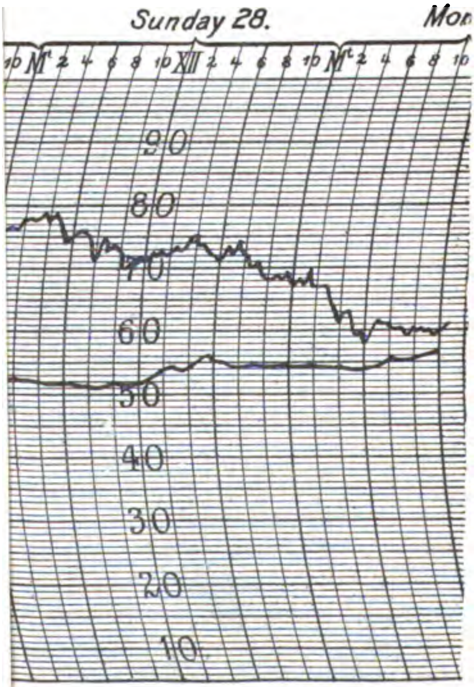
Monthly curves of hourly wind velocities.



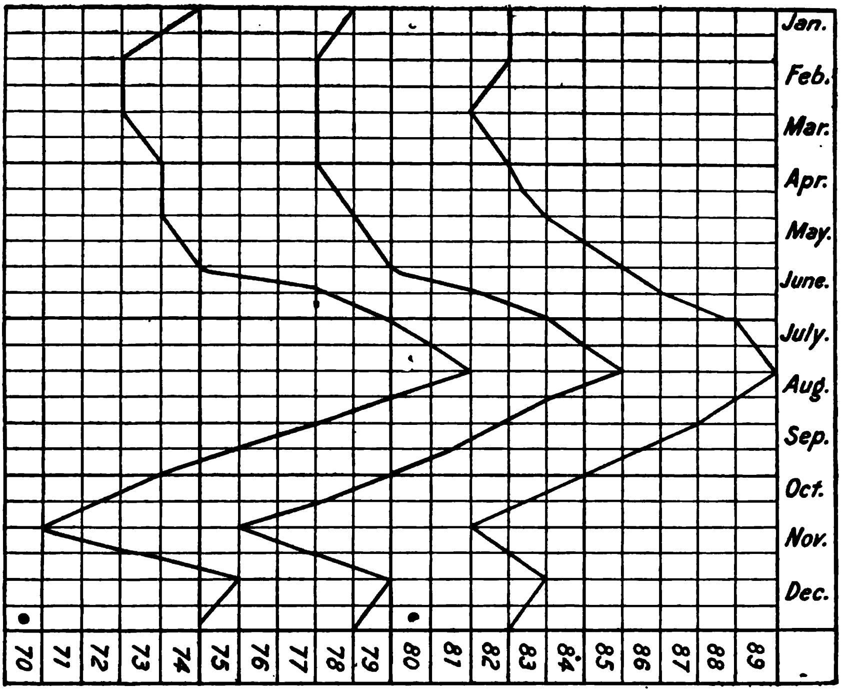
Hourly wind velocities at San Francisco.



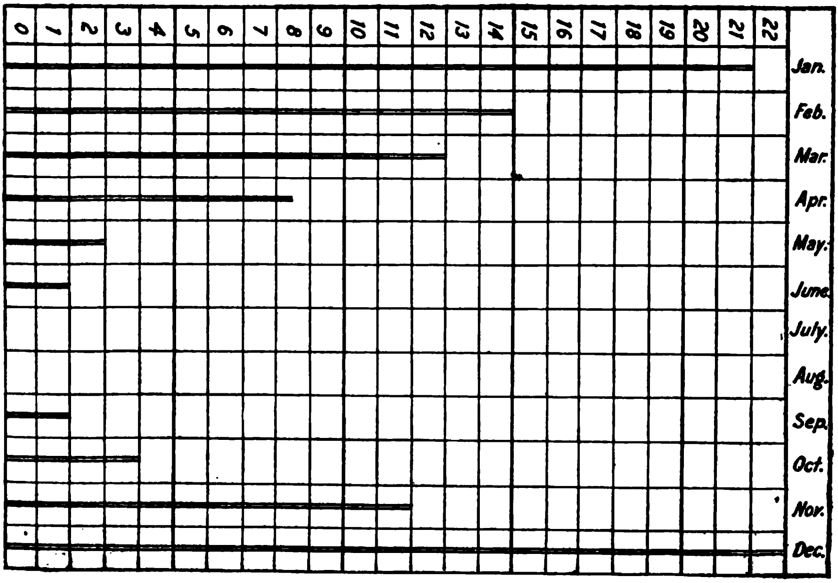
Wednesday 24.
Thursday 25.
6 8 10 XII 2 4 6 8 10 Mt 2 4 6 8 10 XII 2 4 6 8 10 M
90
80
70
60
50
40
feet.
30
20
10
-1



Sunday 28.
Mon
10 Mt 2 4 6 8 10 XII 2 4 6 8 10 Mt 2 4 6 8 10
90
80
70
60
50
40
30
20
10



Mean relative humidity—upper, 5 a. m.; lower, 5 p. m.



Percentage annual rainfall each month.—From Bulletin D, by A. J. Henry.

Rainfall record of Thomas Tennent, made at the foot of Market street, San Francisco, beginning October 1, 1849.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1849.		1851.		1852.		1853.	
	Inches.		*Inches.*		*Inches.*		*Inches.*
Oct. 9	1.20	Feb. 5	0.02	Mar. 27	0.25	May 27	0.01
10	.25	6	.11	31	.30	Aug. 30	.04
30	1.69	18	.04	Apr. 22	.17	Sept. 15	.11
Nov. 2	1.84	20	.12	25	.02	17	.10
4	.25	21	.12	27	.07	24	.02
5	1.18	24	.13	May 17	.32	26	.23
6	1.45	Mar. 18	.23	Oct. 28	.80	Oct. 10	.10
8	1.94	19	.40	Nov. 9	.02	17	.02
10	.71	20	.08	11	.40	Nov. 9	.11
13	.45	21	.02	13	.30	10	.02
16	.84	22	.03	14	.80	11	.02
Dec. 3	.45	24	.03	15	.25	12	.15
11	1.30	25	.22	17	.20	13	.08
12	.84	27	.38	18	.62	14	.25
13	.15	28	.22	21	1.10	15	.37
16	.34	29	.21	23	.12	17	.14
17	.05	30	.12	28	.30	18	.02
18	.22	Apr. 2	.28	29	1.16	25	.68
19	1.21	3	.18	30	.04	26	.40
20	.37	4	.06	Dec. 1	.82	27	.04
21	.54	8	.42	2	.06	Dec. 4	.05
26	.41	9	.06	3	.19	5	.01
31	.32	16	.13	4	.21	9	.20
		17	.06	5	.20	10	1.35
1850.		19	.04	14	.52	12	.11
		May 18	.58	15	.03	13	.02
Jan. 1	.25	19	.06	16	.20	19	.10
2	1.10	20	.03	17	3.00	20	.33
4	.15	June 6	.02	18	1.40	22	.01
6	.05	Aug. 17	.02	19	.05	23	.02
8	1.45	Sept. 7	1.03	21	.21	28	.12
13	.25	Oct. 2	.18	22	.07		
14	.60	7	.03	23	.76	1854.	
17	.25	Nov. 8	1.47	24	.11		
20	.15	16	.37	25	2.54	Jan. 12	.59
22	.05	18	.03	28	.31	13	1.22
23	.58	20	.24	29	1.72	14	.27
24	.48	29	.10	30	.75	15	.29
25	.25	Dec. 2	.03	31	.05	16	.32
26	.53	3	.85			18	.15
29	2.20	4	.12	-1853.		22	.01
Feb. 4	.45	5	.23			23	.42
6	.15	19	.28	Jan. 3	.02	24	.55
22	.18	20	.14	4	.04	25	.06
26	.99	21	.06	5	.69	Feb. 4	.22
Mar. 1	.12	22	2.00	6	.01	5	.51
6	.84	23	.55	7	2.06	6	.16
7	1.05	24	.60	8	.13	9	.70
8	.71	25	.20	10	.20	10	.52
15	.76	26	.30	11	.33	11	.12
18	.58	27	.26	14	.18	12	1.06
22	.47	28	.24	27	.25	19	.01
Apr. 19	.32	29	.30	28	.01	20	.05
25	.12	30	.82	Feb. 22	.29	21	.91
26	.02	31	.12	23	.15	22	1.10
Sept. 12	.10			24	.37	23	.25
15	.15	1852.		25	.34	25	.56
21	.07			26	.27	26	.48
23	.01	Jan. 2	.07	Mar. 8	.14	27	1.26
Nov. 19	.47	4	.03	14	.76	28	.13
21	.10	28	.16	15	.02	Mar. 2	.02
22	.04	30	.32	27	2.85	3	.20
23	.11	Feb. 6	.05	28	.62	4	.07
24	.02	17	.02	29	.47	12	.07
28	.13	28	.03	Apr. 11	.81	13	2.25
29	.05	29	.04	13	.36	14	.50
Dec. 1	.08	Mar. 1	.30	16	3.45	15	.20
11	.26	2	.15	17	.14	17	.03
13	.35	3	.60	19	.07	19	.13
17	.36	4	.02	20	.11	23	.02
		5	.80	28	.08	29	.02
1851.		6	1.20	29	.35	Apr. 8	.01
		7	.75	May 1	.02	9	.01
Jan. 4	.11	8	1.15	10	.02	10	.03
5	.18	9	.70	11	.25	11	.20
6	.09	10	.32	12	.03	19	.05
7	.22	14	.10	20	.02	20	.43
26	.12	15	.04	24	.03	21	.25

Rainfall record of Thomas Tennent, made at the foot of Market street, San Francisco, beginning October 1, 1849—Continued.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1854.		1855.		1856.		1858.	
	Inches.		*Inches.*		*Inches.*		*Inches.*
Apr. 24	0.42	Nov. 21	0.10	Dec. 23	0.20	Feb. 7	0.03
28	1.72	22	.21	24	.24	13	.05
May 19	.02	23	.13	27	.20	14	.30
June 11	.03	28	.08	29	.08	15	.44
17	.05	30	.08	30	.48	16	.41
Aug. 1	.01	Dec. 3	.10	31	1.89	17	.25
Sept. 3	.04	4	.07			19	.20
10	.06	5	.17	1857.		20	.15
15	.05	6	.30			Mar. 12	.52
Oct. 4	.18	7	1.15	Jan. 2	.15	16	.17
9	.22	10	.23	3	.44	17	.04
10	.23	13	.22	4	.21	24	.40
13	.20	14	.05	5	.12	26	.37
22	.10	15	.20	16	.24	27	1.80
23	.31	19	.24	17	1.19	28	.60
24	.65	20	.38	18	.10	29	1.65
25	.22	21	.75	Feb. 4	.37	Apr. 1	.42
26	.32	22	.10	5	.43	4	.27
Nov. 18	.32	26	.80	10	.07	7	.72
22	.02	27	1.00	11	.05	8	.14
Dec. 2	.02			12	.31	May 19	.23
3	.04	1856.		13	.53	20	.06
7	.06			14	1.27	21	.05
31	.75	Jan. 8	.38	15	1.30	June 18	.05
		9	1.05	16	.84	July 27	.02
1855.		10	1.04	18	.04	28	.03
		11	.72	19	.04	Aug. 14	.04
Jan. 1	1.26	14	.67	24	.87	26	.12
2	.32	15	.32	25	1.17	Oct. 20	.30
3	.80	20	.55	26	.85	21	2.06
4	.15	21	.10	27	.45	23	.12
5	.03	22	1.14	Mar. 1	.13	24	.26
6	.08	23	.47	8	.03	Nov. 19	.27
7	.32	24	1.22	21	.18	20	.20
8	.29	25	1.08	22	.03	21	.14
9	.17	30	.66	24	.29	22	.04
30	.19	Feb. 4	.03	27	.36	26	.04
31	.06	19	.12	28	.47	Dec. 4	.07
Feb. 1	.09	20	.33	31	.13	5	.27
7	.05	28	.02	May 6	.01	10	1.80
8	.24	Mar. 14	1.02	10	.02	11	1.02
10	.22	28	.05	30	.02	12	.08
22	.15	29	.10	June 29	.12	14	.17
23	.11	30	.20	Aug. 10	.03	17	.06
25	.25	31	.23	28	.02	21	.05
26	1.29	Apr. 2	.32	Oct. 6	.17	23	.42
27	.52	9	.21	7	.44	24	.64
28	1.85	10	.58	8	.32	26	.28
Mar. 1	.54	11	1.04	Nov. 2	10	27	1.04
2	.34	12	.17	3	.35	28	.20
3	.16	30	.62	4	.88	31	.04
4	.56	May 19	.28	5	.31		
5	.10	21	.08	24	.15	1859.	
7	.23	22	.40	25	.49		
8	.03	June 1	.03	26	.14	Jan. 27	.05
12	.20	July 26	.02	27	.17	28	.21
13	.04	Sept. 10	.02	28	.04	30	.17
14	.03	11	.05	29	.33	31	.85
30	1.21	Oct. 7	.31	30	.05	Feb. 1	.24
31	1.20	14	.01	Dec. 4	.15	6	.16
Apr. 1	.10	16	.02	5	.20	7	.08
10	.80	17	.03	6	.26	8	.54
11	.38	24	.08	9	.22	9	.11
12	.17	Nov. 15	.16	10	.43	10	.12
13	.50	16	.06	11	1.68	11	.62
14	1.65	17	.20	12	.22	12	.78
15	1.05	20	.90	24	.98	13	.14
16	.19	21	.17			15	.34
17	.10	22	.70	1858.		16	.14
27	.05	24	.22			17	1.04
May 2	.03	28	.06	Jan. 7	.03	23	.13
11	.05	29	.32	10	.25	24	.34
13	.30	Dec. 7	.15	11	.37	25	.12
14	1.15	11	.28	12	.40	26	.08
19	.10	12	.21	13	.51	27	1.11
20	.25	14	.04	20	.83	28	.23
Nov. 10	.02	15	.03	21	.55	Mar. 3	.21
13	.05	17	.45	22	1.42	4	.29

Rainfall record of Thomas Tennent, made at the foot of Market street, San Francisco, beginning October 1, 1849—Continued.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1859.	*Inches.*	1860.	*Inches.*	1861.	*Inches.*	1862.	*Inches.*
Mar. 7	0.20	Apr. 8	0.44	Mar. 30	0.03	Mar. 28	0.07
8	.20	19	.09	Apr. 2	.16	29	.20
20	.15	May 2	.12	3	.15	30	.20
21	1.07	3	.62	4	.03	Apr. 1	.11
22	.73	4	.43	24	.17	2	.13
26	.03	5	.12	May 3	.10	3	.07
27	.04	11	.17	20	.65	4	.01
29	.03	18	.39	21	.25	8	.09
30	.07	22	.35	June 5	.04	9	.17
Apr. 8	.13	23	.28	12	.04	11	.01
10	.03	24	.04	Sept. 2	.02	13	.02
11	.02	25	.28	Nov. 10	.27	14	.12
30	.09	26	.06	12	.74	May 2	.02
May 1	.38	June 6	.07	13	.29	8	.56
2	1.07	28	.02	14	.05	11	.03
22	.06	July 10	.21	15	.08	12	.11
23	.04	Oct. 3	.01	16	.39	18	.02
Aug. 3	.02	4	.12	17	.22	June 11	.05
Sept. 15	.03	5	.08	19	.56	Oct. 4	.05
Oct. 23	.05	6	.01	26	.48	16	.07
Nov. 2	.06	17	.04	27	.60	29	.02
3	.36	19	.17	29	.08	30	.38
4	.90	20	.08	30	.34	Nov. 6	.11
5	.84	24	.12	Dec. 1	.05	7	.02
6	.92	27	.03	3	.07	10	.02
7	.80	28	.11	6	1.02	Dec. 9	.19
8	.13	29	.04	7	.29	18	.12
17	.07	30	.10	8	1.65	20	.05
21	.14	Nov. 11	.21	9	.18	21	.32
22	.23	12	.35	16	.01	22	1.01
23	.25	28	.02	22	.03	23	.17
24	.31	Dec. 1	.02	23	1.06	24	.14
25	1.73	6	.04	24	.56	30	.22
26	.51	7	.13	26	2.02	31	.13
30	.03	10	.02	27	.23		
Dec. 4	.04	11	.13	28	.17	1863.	
23	.21	12	.07	29	.70		
24	.63	14	.37	30	1.25	Jan. 1	.27
25	.38	15	.23	31	.25	3	.12
26	.21	16	.78			4	.71
27	.10	17	.04	1862.		5	.46
		18	.26			11	.15
1860.		19	.27	Jan. 5	2.67	19	.74
		20	.21	6	1.49	20	.36
Jan. 1	.08	21	.15	8	1.35	22	.76
2	.07	22	.58	9	3.50	23	.06
3	.24	23	1.03	10	2.46	Feb. 5	.44
4	.21	24	.77	11	1.25	6	.16
5	.56	25	.63	13	.22	8	.11
6	.22	26	.13	15	.49	11	.16
7	.23	27	.07	16	2.46	12	.71
22	.03	31	.23	17	2.64	14	.11
Feb. 7	.60			18	.52	16	.40
12	.10	1861.		19	.72	17	.58
13	.43			20	1.69	18	.47
16	.04	Jan. 1	.21	21	.55	20	.05
17	.17	4	1.03	22	1.00	Mar. 7	.05
18	.14	5	.49	27	.04	17	.16
29	.12	6	.23	29	.76	18	.19
Mar. 1	.40	15	.03	30	.55	19	.11
5	.37	19	.14	Feb. 2	.79	20	.56
6	.03	20	.22	5	.04	24	.04
10	.13	23	.12	19	.44	25	.07
12	.03	Feb. 7	.06	21	2.09	26	.88
15	.10	9	.12	22	.80	Apr. 8	.19
16	.17	10	.14	23	.84	13	.12
22	.89	11	2.02	24	.33	14	.10
23	.11	21	.21	25	1.49	15	.38
27	.05	23	.08	26	.88	16	.32
28	.90	24	.10	27	.83	20	.24
29	.62	25	.99	Mar. 7	.02	21	.10
31	.69	Mar. 23	.79	9	.01	26	.12
Apr. 1	.49	24	.07	10	.47	27	.04
3	.05	25	.04	11	.57	May 18	.14
4	1.32	26	2.53	12	.18	19	.09
5	.65	27	.40	14	.25	Sept. 19	.03
6	.06	28	.04	15	.11	Nov. 11	.05
7	.04	29	.18	16	.12	12	.07

Rainfall record of Thomas Tennent, made at the foot of Market street, San Francisco, beginning October 1, 1849—Continued.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1863.		1865.		1866.		1867.	
	Inches.		*Inches.*		*Inches.*		*Inches.*
Nov. 14	0.87	Jan. 26	0.38	Mar. 18	0.21	Mar. 21	0.34
15	.92	27	.74	19	.41	30	.05
16	.64	28	.91	20	.23	31	.30
Dec. 1	.33	31	1.50	25	.36	Apr. 1	.32
9	.15	Feb. 13	.30	29	.02	2	.15
10	.05	14	.10	30	.11	5	.40
11	.02	15	.08	31	.49	6	.15
13	.27	16	.12	Apr. 29	.12	9	.02
21	.37	18	.40	May 21	.06	10	.67
23	.52	19	.24	22	.22	11	.50
24	.09	27	.05	25	1.05	12	.15
		28	.05	26	.01	Sept. 14	.04
1864.		Mar. 3	.21	27	.05	Oct. 5	.20
		4	.38	28	.07	Nov. 5	.62
Jan. 1	.12	12	.07	June 8	.04	6	.75
5	.39	19	.08	Sept. 6	.07	19	.79
15	.14	Apr. 6	.21	15	.04	21	.75
29	.37	7	.62	Nov. 2	.68	24	.44
31	.81	9	.11	3	.25	25	.06
Mar. 15	.03	May 18	.45	4	.14	Dec. 1	.02
17	.04	19	.18	5	.31	2	.18
18	.89	Sept. 24	.06	9	.07	7	.15
20	.02	26	.18	16	.26	8	.55
27	.06	Oct. 7	.03	19	.02	9	.24
28	.14	8	.07	24	.38	10	.33
29	.09	25	.01	25	.29	16	.04
30	.07	30	.15	26	.28	17	1.62
31	.18	Nov. 13	.18	29	.14	18	.69
Apr. 1	.91	14	.37	30	.53	20	.48
3	.35	16	.07	Dec. 1	.53	21	.84
4	.23	17	1.03	8	.13	22	1.68
26	.08	18	.27	11	.53	23	.72
May 10	.01	19	.06	12	.01	24	.08
11	.10	20	.06	15	.63	25	1.35
13	.01	21	.63	16	.43	29	.06
14	.11	22	1.12	18	.95	30	.21
17	.55	30	.40	19	4.28	31	1.45
Aug. 22	.11	Dec. 1	.01	20	3.62		
23	.03	2	.01	21	.64	1868.	
24	.07	8	.04	22	.31		
Sept. 7	.01	13	.06	24	.06	Jan. 1	.93
Oct. 24	.02	22	.04	25	.71	2	.33
26	.05	23	.15	26	.56	3	.12
27	.06	24	.25	27	.82	4	.15
Nov. 15	.14	26	.02	28	.63	8	.66
23	.05			29	.40	11	.12
25	.48	1866.		30	.42	12	.87
26	3.98					13	.43
27	.42	Jan. 5	.30	1867.		16	.12
28	.44	6	.19			18	.41
29	.50	7	.41	Jan. 1	.03	19	.43
30	.67	8	1.51	4	.18	20	.64
Dec. 2	.33	10	.40	5	.65	22	1.08
3	.13	11	.46	6	.51	23	.99
4	.03	12	.60	11	.11	24	.84
5	.04	13	.60	12	.75	25	.36
6	.92	16	.23	14	.05	26	1.02
10	.01	17	2.17	19	.23	Feb. 7	.06
11	1.06	19	.11	20	.18	21	.64
12	2.56	20	2.22	21	.58	22	.54
13	.99	21	1.14	22	.17	23	.14
14	.04	22	.15	23	.40	24	.86
15	.27	23	.08	24	.35	25	.69
23	.38	24	.31	26	.78	26	1.61
25	.47	Feb. 1	.36	30	.19	27	1.02
26	.81	2	.16	Feb. 18	.49	28	.87
28	.02	3	.43	19	.15	29	.20
29	.04	4	.19	20	.12	Mar. 1	.56
30	.30	5	.22	21	2.22	2	.20
31	.52	9	.16	22	.30	3	1.55
		12	.06	25	.08	4	.55
1865.		27	.07	26	.14	11	.19
		28	.47	27	1.02	13	.56
Jan. 1	.51	Mar. 5	.02	28	.68	14	.44
6	.08	6	.21	Mar. 1	.17	15	.14
18	.07	8	.66	2	.16	20	.16
24	.07	9	.30	8	.40	21	1.05
25	.88	17	.02	17	.16	22	.90

Rainfall record of Thomas Tennent, beginning October 1, 1849, and ending February 28, 1871.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1868.		1869.		1871.		1872.	
	Inches.		*Inches.*		*Inches.*		*Inches.*
Apr. 3......	0.10	June 15......	0.02	Jan. 17......	0.21	Feb. 14......	0.12
7......	.20	Sept. 1......	.12	18......	.78	15......	.02
9......	.38	Oct. 18......	.02	22......	.28	16......	.49
10......	.30	19......	.17	23......	.62	17......	.22
11......	.70	20......	.36	28......	.44	18......	.08
12......	.47	21......	.74	Feb. 4......	.37	21......	.42
13......	.06	Nov. 6......	.14	6......	.12	22......	.73
14......	.04	10......	.65	8......	.02	24......	1.28
15......	.06	11......	.20	13......	.14	25......	.02
May 13......	.01	12......	.05	14......	.13	26......	.13
19......	.02	13......	.05	15......	.67	27......	.94
June 1......	.01	27......	.04	20......	.72	Mar. 1......	.16
12......	.05	28......	.06	21......	1.02	5......	.73
23......	.17	Dec. 7......	.41	22......	.28	8......	.02
Oct. 1......	.06	8......	1.10	23......	.29	9......	.28
2......	.08	10......	.13	Mar. 6......	.26	12......	.19
4......	.01	11......	.14	12......	.02	27......	.02
Nov. 4......	.05	22......	.22	14......	.01	31......	.19
18......	.30	23......	.46	15......	.01	Apr. 13......	.06
19......	.64	24......	.51	17......	.12	15......	.35
25......	.08	25......	1.34	18......	.02	16......	.22
29......	.11			19......	.28	17......	.04
Dec. 4......	.01	1870.		23......	.57	19......	.30
17......	.05			25......	.02	26......	.09
18......	.55	Jan. 10......	.09	Apr. 4......	.13	27......	.02
21......	.07	11......	.11	5......	.07	May 24......	.02
22......	.18	12......	.14	6......	1.28	30......	.01
23......	1.20	13......	.35	8......	.01	31......	.15
24......	.29	14......	.53	16......	.39	June 4......	.02
25......	.47	15......	.31	17......	.01	5......	.01
26......	.92	18......	.76	May 7......	.01	16......	.01
29......	.18	19......	1.03	16......	.04	July 27......	.01
30......	.32	20......	.27	27......	.05	Sept. 26......	.04
31......	.10	22......	.30	29......	.13	Oct. 26......	.11
		Feb. 9......	.41	June 14......	.01	Nov. 4......	.15
1869.		10......	.02	Aug. 5......	.02	12......	.43
		12......	.14	Oct. 27......	.07	13......	.01
Jan. 1......	1.28	14......	.11	Nov. 3......	.09	28......	.01
2......	.53	15......	.34	14......	.01	29......	2.06
7......	.10	19......	.08	15......	.27	30......	.13
10......	.01	20......	.86	25......	.12	Dec. 4......	.02
11......	.07	21......	.25	26......	1.20	22......	.63
14......	.08	22......	.90	27......	.11	23......	.42
22......	.15	23......	1.57	28......	1.01	24......	1.48
23......	1.45	24......	.10	Dec. 2......	.10	25......	1.39
24......	.19	Mar. 1......	.11	17......	.25	26......	1.47
25......	.25	10......	.02	18......	2.83	27......	.06
26......	.20	11......	.14	19......	3.12	28......	.32
27......	.15	12......	.18	20......	.30	29......	.06
28......	.54	16......	.22	21......	.91	30......	.05
29......	1.10	17......	1.05	23......	2.48	31......	.05
30......	.25	23......	.27	24......	.19		
Feb. 2......	.44	30......	.01	26......	.04	1873.	
3......	.30	Apr. 1......	.46	27......	1.05		
7......	.20	2......	.21	28......	.40	Jan. 1......	.06
8......	.82	3......	.09	29......	.82	2......	.09
9......	.32	8......	.01	30......	.17	3......	.06
10......	1.67	11......	.16	31......	1.70	5......	.10
11......	.15	12......	.58			8......	.01
Mar. 12......	.05	May 2......	.02	1872.		11......	.12
13......	.08	19......	.18			30......	.12
14......	.10	Sept. 30......	.03	Jan. 2......	.01	31......	1.02
15......	.14	Nov. 4......	.01	3......	.71	Feb. 1......	.02
16......	.63	6......	.02	5......	.19	2......	.27
17......	.55	7......	.22	6......	.08	3......	.13
18......	.18	29......	.18	7......	.05	4......	.27
19......	.48	Dec. 1......	.59	8......	2.36	5......	.01
20......	.67	2......	.57	9......	.34	8......	.64
24......	.01	5......	1.42	11......	.17	9......	.23
26......	.10	6......	.12	12......	.01	11......	.19
29......	.15	7......	.32	13......	.01	12......	.16
Apr. 7......	.28	13......	.09	31......	.07	13......	.05
16......	.45	14......	.27	Feb. 2......	.07	15......	.12
17......	.69			4......	.16	16......	.13
18......	.68	1871.		7......	.46	18......	.82
19......	.09			8......	.65	24......	.05
May 19......	.06	Jan. 9......	.42	9......	.69	26......	.02
21......	.02	10......	.32	11......	.42	27......	.75

Rainfall record of the Signal Service, San Francisco, beginning March 1, 1871—Cont'd.

Date.	Rainfall.
1873.	
	Inches.
Feb. 28	0.08
Mar. 5	.47
6	.10
15	.11
16	.09
29	.01
30	.01
Apr. 2	.05
20	.14
21	.22
28	.02
June 2	.01
16	.01
July 22	.01
Aug. 5	.05
25	.03
Oct. 6	.06
7	.77
Nov. 6	.82
21	.04
29	.01
30	.79
Dec. 1	.03
3	1.61
4	.85
5	1.01
6	.15
7	.42
8	.10
9	.91
13	.06
14	.27
15	.14
16	.57
18	.04
19	.39
22	.34
28	.29
29	1.16
30	1.34
31	.04
1874.	
Jan. 1	.89
2	.77
14	.05
15	.38
16	.89
17	.79
18	.04
19	.82
20	.02
21	.08
22	.01
25	.31
26	.03
27	.11
28	.62
30	.24
31	.11
Feb. 2	.80
6	.01
9	.11
10	.15
11	.03
12	.23
13	.81
14	.20
16	.08
17	.28
25	.01
Mar. 1	.58
3	.26
5	.13
7	.06
8	.24
11	.26
1874.	
	Inches.
Mar. 12	0.65
13	.05
14	.53
15	.08
16	.01
25	.10
26	.02
27	.39
Apr. 3	.04
5	.04
12	.70
13	.02
30	.10
May 1	.23
4	.03
5	.13
6	.20
22	.04
23	.03
June 6	.09
7	.04
23	.01
Sept. 3	.02
Oct. 1	.02
9	.17
13	.02
16	.03
18	.11
21	.28
22	.03
25	1.58
26	.25
27	.20
Nov. 4	.04
5	1.34
7	.04
22	.10
23	3.98
24	1.05
Dec. 1	.06
2	.05
3	.05
15	.02
25	.15
1875.	
Jan. 10	.01
11	.04
13	.07
14	1.48
16	.20
18	1.87
19	1.92
20	.01
22	.53
23	1.76
24	.06
25	.06
Feb. 1	.27
2	.04
25	.01
Mar. 2	.45
4	.23
22	.01
24	.22
25	.01
27	.05
28	.33
Apr. 5	.06
30	.04
May 6	.01
8	.14
14	.07
June 13	.09
15	.53
16	.40
Oct. 27	.22
1875.	
	Inches.
Oct. 28	0.02
Nov. 1	.47
6	.16
7	.01
11	.11
13	.57
14	.10
15	.29
16	.47
17	2.30
18	1.13
19	.05
20	.03
23	.05
24	.17
25	.01
26	1.18
30	.27
Dec. 1	.52
3	.44
4	.10
19	.38
24	.06
25	.83
26	.19
28	1.50
29	.02
31	.11
1876.	
Jan. 1	.22
2	.52
3	1.47
4	.13
6	.20
7	1.29
8	.15
19	.25
20	.18
21	.04
22	.65
23	1.50
24	.42
25	.12
26	.36
27	.04
31	.01
Feb. 7	.21
8	1.80
9	.21
11	1.35
12	.01
24	.30
25	.13
27	.90
28	.01
Mar. 2	.94
3	1.03
4	.32
5	.02
6	.84
7	1.13
8	.60
12	.22
13	.17
29	.22
Apr. 2	.23
7	.60
9	.18
18	.09
21	.15
29	.04
May 19	.15
20	.09
June 20	.04
July 6	.01
Aug. 14	.01
1876.	
	Inches.
Sept. 4	0.20
29	.18
Oct. 16	.53
17	.49
18	.43
25	.09
27	1.06
28	.56
29	.20
Nov. 4	.06
16	.19
1877.	
Jan. 16	.34
17	.57
18	.21
19	.35
21	.08
28	.44
29	.62
30	1.63
31	.08
Feb. 1	.33
2	.01
12	.52
13	.10
20	.01
22	.05
25	.16
Mar. 1	.04
2	.32
6	.15
9	.01
10	.56
Apr. 3	.03
8	.08
14	.04
15	.02
16	.07
19	.02
May 28	.18
June 27	.01
July 16	.02
Oct. 21	.27
22	.35
23	.01
25	.02
Nov. 2	.08
4	.21
5	.25
6	.07
11	.56
14	.04
15	.06
16	.17
22	Trace.
23	.13
Dec. 1	.23
16	.23
17	.99
21	.36
23	.49
28	.36
1878.	
Jan. 6	.02
7	.28
8	.59
10	.84
13	Trace.
14	.52
15	1.94
16	1.97
17	Trace.
18	.28
19	.10

Rainfall record of the Signal Service, San Francisco, beginning March 1, 1871—Cont'd.

Date.	Rainfall.
1878.	*Inches.*
Jan. 20	Trace.
21	0.13
22	1.15
23	Trace.
24	1.68
25	.02
26	.13
27	1.13
28	.17
29	.02
30	.78
31	.72
Feb. 4	.95
5	Trace.
6	.66
7	.33
8	.14
10	.02
11	1.78
12	.17
13	.61
14	1.92
16	.42
17	.92
18	1.25
19	.39
20	.14
23	.60
24	.40
26	1.16
27	.47
28	.19
Mar. 3	.57
4	.03
5	Trace.
6	1.01
7	.07
10	.07
13	.73
14	.26
17	.05
18	.01
19	Trace.
20	.16
21	.30
24	.28
25	.15
26	.15
27	.37
28	.02
29	.15
30	.18
Apr. 4	Trace.
14	.16
15	.29
19	.61
20	Trace.
May 20	.05
21	.09
30	.02
June 6	Trace.
7	.01
July 17	.01
Sept. 17	Trace.
27	.03
28	.07
29	.11
30	.34
Oct. 14	1.27
Nov. 4	.11
5	.01
14	.45
Dec. 6	.14
7	.01
9	.08
29	.04
30	.31
1879.	*Inches.*
Jan. 9	0.22
10	.83
11	.01
13	.28
16	.05
22	.04
23	1.04
24	.29
25	.33
26	.15
27	Trace.
28	.26
30	.02
Feb. 8	.10
9	1.66
10	.11
11	.78
12	.98
13	.04
15	.51
16	.04
17	.66
18	.02
Mar. 2	.13
4	1.57
5	2.73
6	1.14
7	.95
8	.13
9	1.05
18	.25
19	.20
20	.16
21	.03
22	.32
24	.01
25	Trace.
26	.08
Apr. 4	.03
5	.11
6	.30
7	.10
8	.07
10	.24
13	.13
14	.12
18	.01
19	.26
20	.52
May 6	.05
17	.93
18	.22
19	.74
28	.41
June 10	.05
July 9	.01
Aug. 22	.02
Sept. 23	Trace.
Oct. 6	.43
7	.13
11	.07
12	.15
15	Trace.
Nov. 5	.03
6	.14
8	.07
9	.94
11	.05
12	.16
13	.19
14	.21
29	.86
30	1.38
Dec. 1	.08
2	.23
3	.37
5	.68
1879.	*Inches.*
Dec. 7	0.23
8	.14
9	.09
10	.09
18	.04
19	1.55
20	.11
21	.42
22	.20
28	.23
1880.	
Jan. 7	.24
8	.12
9	1.03
10	.03
25	.16
26	.47
27	.06
Feb. 9	.31
10	.18
15	.14
18	.58
19	.22
21	.33
22	.06
23	.05
Mar. 2	.09
3	.57
4	.01
17	.38
23	.23
24	.15
27	.09
28	.48
29	.05
31	.03
Apr. 1	.25
2	1.85
3	.12
4	Trace.
5	.05
6	.59
9	.77
10	Trace.
12	.11
13	.07
14	.59
15	1.33
16	.27
17	.06
18	.09
19	.48
20	1.81
21	1.39
22	.23
May 2	Trace.
4	.05
5	.11
10	.03
11	.84
12	.09
Oct. 1	Trace.
4	Trace.
8	.05
Nov. 1	.01
23	.31
24	.01
Dec. 1	1.22
2	1.50
3	.72
4	.04
5	.50
8	Trace.
9	.08
14	1.81
1880.	*Inches.*
Dec. 15	0.36
16	.26
17	.43
18	.25
19	1.66
20	.79
21	Trace.
22	.27
23	.47
24	.98
25	.42
27	.41
29	.16
1881.	
Jan. 13	.77
14	.74
15	.09
16	.17
19	.04
20	.01
26	.01
28	1.18
29	4.67
30	.96
31	.05
Feb. 1	.01
2	Trace.
3	1.00
4	.06
5	.11
7	.29
8	.08
9	.01
12	.10
13	.38
15	.28
16	1.37
25	.12
26	.83
27	.01
Mar. 1	.02
8	.05
9	.67
11	Trace.
15	.11
24	Trace.
26	.01
27	.04
Apr. 5	.22
6	.02
8	Trace.
9	.25
10	.34
16	Trace.
17	1.09
18	.01
22	.01
23	.06
May 9	.05
21	Trace.
31	.17
June 3	.41
7	.28
10	Trace.
Sept. 22	.25
Oct. 3	.10
15	Trace.
25	.01
26	.20
27	.01
28	.12
30	.10
Nov. 15	1.34
16	.30
17	.02

Rainfall record of the Signal Service, San Francisco, beginning March 1, 1871—Cont'd.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1881.		1882.		1883.		1884.	
	Inches.		*Inches.*		*Inches.*		*Inches.*
Nov. 28	0.10	Oct. 10	0.19	Oct. 25	0.08	June 11	0.27
29	.02	13	.39	26	1.19	12	.96
30	.16	24	.03	27	.05	13	.48
Dec. 1	.27	30	.01	28	Trace.	21	Trace.
2	.02	Nov. 1	.37	Nov. 7	.87	22	.09
3	.18	2	1.85	8	.45	23	.10
4	.87	3	1.63	24	.28	24	Trace.
5	.60	7	Trace.	Dec. 2	.11	Aug. 4	.03
6	.02	9	.13	21	.28	24	.01
9	.15	21	.01	23	.15	Sept. 7	.12
10	.03	23	.15	24	.17	8	.09
11	.31	26	.03	25	.12	30	.12
15	.52	29	.01	26	.01	Oct. 12	.07
24	.38	30	Trace.	27	.07	13	1.10
26	.37	Dec. 11	.07	28	.01	14	.64
27	.18	12	.01	29	Trace.	15	.74
		18	.30			Nov. 9	.07
1882.		19	.55	1884.		12	.19
		20	.01			Dec. 16	.10
Jan. 2	.12	22	.08	Jan. 3	.16	17	.60
3	.08	24	.09	5	.48	18	.57
4	.14	28	.14	8	.04	19	.63
5	.03	31	.76	25	.08	20	1.62
6	.06			26	.50	21	.28
23	.40	1883.		27	.38	22	.48
24	.22			28	.09	23	2.01
25	.06	Jan. 1	.57	29	1.44	24	.52
26	.33	4	Trace.	30	.75	25	.37
31	.24	17	.03	31	.02	26	.41
Feb. 9	.03	24	.91	Feb. 1	.18	27	.02
10	.80	25	.39	2	.02	28	.07
11	.07	29	.02	3	.29		
12	.28	Feb. 6	.13	4	.66	1885.	
13	.05	10	Trace.	5	.83		
16	.41	11	Trace.	6	.22	Jan. 1	.42
23	.10	12	Trace.	7	.20	2	.03
24	.52	13	.40	10	.01	7	.05
25	.06	14	.51	11	.01	8	.01
26	.60	Mar. 11	Trace.	14	.65	9	.52
27	.04	12	.01	15	1.17	10	.50
Mar. 1	.04	25	Trace.	16	1.29	11	.29
2	.02	26	1.55	17	.78	13	.47
4	Trace.	27	.48	18	.23	27	.15
9	.13	28	.46	20	.11	28	.02
10	.73	29	.30	Mar. 3	.04	29	.06
11	.34	30	.18	4	.02	30	.01
12	.13	31	.03	5	.07	Feb. 1	.02
13	.66	Apr. 2	.09	6	.45	2	.06
14	.49	3	.46	7	.51	18	.09
15	.63	7	Trace.	8	1.39	19	.06
16	.06	8	Trace.	9	1.94	20	.06
17	Trace.	11	.02	10	.07	21	.01
18	.18	12	.10	14	1.03	Mar. 9	Trace.
19	.04	19	.76	15	.04	10	Trace.
Apr. 2	.01	20	Trace.	18	.06	18	.55
3	.03	25	Trace.	22	.08	25	.12
5	.30	30	.08	25	1.00	30	.16
8	.27	May 1	.01	26	.12	31	.18
9	.44	4	1.21	27	.97	Apr. 2	Trace.
10	Trace.	5	.88	28	.45	3	.01
19	.06	6	.58	Apr. 8	.04	4	.04
22	.05	7	Trace.	9	1.43	5	.03
24	.06	8	.03	10	1.24	6	.07
25	Trace.	11	.05	11	1.41	7	1.44
May 1	.02	12	.07	12	.30	8	1.11
2	.14	13	.04	13	.04	9	.25
3	.02	15	.58	14	1.14	10	.02
24	.03	16	.05	15	.32	16	.01
June 5	Trace.	31	.02	23	.15	17	.19
6	.02	June 1	.01	24	Trace.	19	Trace.
9	Trace.	11	Trace.	26	.26	26	Trace.
18	Trace.	Sept. 2	Trace.	May 18	.10	28	.01
19	.02	21	Trace.	24	.12	May 10	Trace.
Sept. 30	.26	29	.28	25	.01	12	Trace.
Oct. 1	.20	30	.14	June 1	Trace.	13	Trace.
3	1.40	Oct. 22	Trace.	7	Trace.	14	.04
6	.29	23	Trace.	8	.54	18	Trace.
7	.15	24	.10	9	.13	31	Trace.

Rainfall record of the Signal Service, San Francisco, beginning March 1, 1871—Cont'd.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1885.		1886.		1887.		1888.	
	Inches.		*Inches.*		*Inches.*		*Inches.*
June 4	Trace.	Mar. 15	Trace.	Feb. 21	0.84	Feb. 1	0.05
9	0.09	16	0.01	24	.32	10	.20
10	.10	17	.65	Mar. 1	Trace.	11	.24
21	Trace.	23	Trace.	2	.14	12	.34
July 2	.01	31	.26	3	.52	13	Trace.
8	.05	Apr. 1	.49	4	.08	14	.10
Sept. 5	Trace.	2	.03	17	.06	17	.01
24	.11	6	.49	18	.04	Mar. 1	.90
Oct. 13	.40	7	.24	Apr. 6	.43	2	.35
14	.31	8	.08	7	.02	3	.18
16	Trace.	9	1.01	8	1.37	4	1.21
29	.01	10	1.14	9	.18	5	.17
Nov. 1	.01	11	.30	12	.01	7	.05
3	.03	12	.36	13	.04	8	.02
4	.78	13	.28	14	Trace.	13	.15
7	.17	15	.23	19	Trace.	14	Trace.
8	.03	16	.32	20	.25	23	Trace.
9	.45	17	31	29	.05	24	.02
10	.42	May 4	Trace.	May 6	.01	29	Trace.
14	1.20	5	.02	9	.02	30	.26
15	.86	7	.21	19	Trace.	31	.29
16	1.67	8	Trace.	24	Trace.	Apr. 3	Trace.
17	.52	9	.14	31	.03	4	.11
18	.01	23	Trace.	June 4	Trace.	May 3	.19
19	.20	26	Trace.	13	.07	4	.04
20	.18	June 4	.01	July 8	Trace.	15	.03
21	.51	July 16	.23	31	Trace.	24	.03
22	Trace.	Sept. 30	.01	Aug. 1	.01	30	.09
23	2.58	Oct. 16	.72	Sept. 5	.04	June 1	.03
24	.05	18	.03	6	.17	2	.02
28	.04	27	.08	7	.01	3	.01
29	.35	28	.01	21	.02	6	Trace.
Dec. 10	.29	29	.04	22	.05	10	.02
14	.05	30	.60	Nov. 3	Trace.	13	.01
15	.02	Nov. 8	Trace.	4	Trace.	14	.06
16	Trace.	10	Trace.	5	.01	15	.05
21	2.78	11	.05	6	.01	17	.03
22	.34	13	.02	7	Trace.	19	.04
23	.09	20	.75	11	Trace.	July 11	Trace.
24	.59	21	.02	28	.40	12	Trace.
25	.33	Dec. 6	.15	29	.15	21	.01
26	.48	7	.47	30	.42	Aug. 26	.01
30	.02	8	.98	Dec. 1	.83	Sept. 10	Trace.
		9	.13	2	.11	11	.04
1886.		11	Trace.	3	.07	12	.01
		22	Trace.	4	.08	14	Trace.
Jan. 12	.03	23	.14	7	.03	15	.92
13	.12	28	Trace.	8	.16	30	Trace.
14	.01	29	.16	9	.03	Oct. 6	.02
15	.03	30	.04	10	.01	9	.01
17	.11			12	.04	17	.05
18	.44	1887.		26	.11	30	.05
19	.85			28	.64	Nov. 3	Trace.
20	.96	Jan. 12	Trace.	29	.95	15	1.36
21	.28	13	.05	30	.28	16	.81
22	.52	15	.05			17	.96
23	2.35	18	.02	1888.		18	.13
24	.07	19	.76			19	.01
25	.66	20	.80	Jan. 1	.79	20	.87
26	.84	21	.19	2	.32	21	.01
27	.15	24	Trace.	3	1.43	22	.24
Feb. 7	Trace.	27	.03	4	.62	23	.02
23	.01	Feb. 1	.18	5	.29	25	Trace.
25	Trace.	2	.04	13	.01	26	Trace.
26	.02	4	2.22	16	Trace.	29	.01
27	.03	5	2.92	17	.02	30	.07
28	.18	6	.01	19	Trace.	Dec. 1	.03
Mar. 1	.01	7	.24	20	.93	2	.02
2	.08	8	Trace.	21	.64	8	.03
3	.15	9	.12	22	.09	9	1.01
4	.02	10	.28	23	.10	10	.09
5	.02	11	.50	24	.02	11	.04
6	.03	12	.79	25	Trace.	12	Trace.
7	.16	13	.36	26	Trace.	13	1.51
8	.17	14	.55	27	.14	14	.13
9	.45	15	Trace.	29	.12	15	.74
10	.06	16	.33	30	.27	16	.05
13	Trace.	20	.04	31	1.02	17	Trace.

Rainfall record of the Signal Service and Weather Bureau, San Francisco, b
March 1, 1871.

Date.	Rainfall.
1888.	*Inches.*
Dec. 20	Trace.
21	0.19
22	.35
23	.10
24	.07
25	Trace.
26	1.09
27	.11
29	.24
1889.	
Jan. 3	Trace.
4	.81
10	Trace.
11	.11
12	.11
17	Trace.
18	.14
20	Trace.
21	.10
23	.01
Feb. 6	.01
15	.03
16	.01
18	.06
23	.01
24	.59
25	.01
Mar. 7	.39
8	.20
9	.65
10	.46
11	.08
12	.95
13	2.54
14	.28
15	.78
16	.23
17	.01
18	.52
20	.68
23	.01
27	.05
28	Trace.
29	Trace.
Apr. 2	.08
3	.03
4	.05
6	.04
8	.30
9	.01
10	.02
13	.21
14	Trace.
15	.22
16	Trace.
20	Trace.
21	Trace.
27	Trace.
May 2	.04
4	.15
5	1.29
6	.43
7	.02
8	.06
12	.01
13	.05
14	Trace.
15	.10
June 27	.03
July 10	.01
Oct. 7	1.06
8	.01
17	.70
18	1.33
20	1.25
21	.68
1889.	*Inches.*
Oct. 22	0.05
23	.60
25	.71
26	.72
27	.14
28	.01
29	Trace.
30	.02
Nov. 17	.38
18	.74
19	.58
20	.56
21	.02
22	.35
29	Trace.
30	.27
Dec. 1	.09
2	.03
3	.36
4	.51
5	1.44
6	1.28
7	.53
8	1.44
9	.05
10	.33
11	.34
12	.70
17	.50
18	.69
19	1.12
20	.26
21	.81
22	1.24
23	.09
24	1.42
25	.32
26	.04
28	.08
30	.14
1890.	
Jan. 1	.05
2	.85
3	.37
4	.36
5	.29
6	.02
7	.01
10	.03
12	.48
13	.86
15	.23
16	1.04
17	.45
18	.69
19	.84
20	.03
21	.55
22	.36
23	.16
24	.72
25	1.88
29	.19
30	.20
Feb. 4	.03
5	.04
15	.07
16	1.07
17	.29
18	.70
19	1.27
20	.74
21	.62
22	.23
24	.01
25	.09
1890.	*Inches.*
Mar. 2	Trace.
3	Trace.
4	0.29
5	.04
6	.31
7	.23
8	.65
9	.16
10	.02
18	1.31
19	.72
22	.04
23	.03
25	.08
26	.23
28	Trace.
29	.40
30	.22
Apr. 6	.55
7	Trace.
17	.01
18	.52
19	.02
29	.05
30	.03
May 7	.45
8	.01
10	.45
11	.16
June 17	.05
23	.05
July 8	.02
Sept. 28	Trace.
29	.29
30	.02
Dec. 3	1.83
4	.18
5	.02
24	.26
25	.17
30	.79
1891.	
Jan. 1	.06
2	.15
3	.26
4	.49
5	Trace.
14	Trace.
15	.01
17	.01
Feb. 1	.42
5	.07
6	Trace.
10	.01
11	.01
12	.01
14	.04
15	3.38
16	.54
17	.04
18	.34
19	.02
20	Trace.
21	.46
22	.69
23	.22
24	.12
25	.10
26	.22
27	.18
28	.39
Mar. 1	.68
2	.10
3	.13
4	Trace.
5	.19
1891.	
Mar. 6	
10	
11	
12	
15	
16	
26	
27	
28	
Apr. 5	
6	
7	
8	
9	
10	
11	
13	
14	
16	
17	
18	
19	
23	
May 3	
6	
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14	
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29	
30	
31	
June 11	
12	
17	
July 8	
9	
10	
11	
Aug. 30	
Sept. 5	
9	
10	
13	
15	
22	
Oct. 22	
28	
31	
Nov. 1	
5	
18	
19	
30	
Dec. 1	
3	
4	
8	
9	
16	
19	
23	
26	
27	
28	
29	
30	
31	
1892.	
Jan. 1	
4	
7	
8	
25	
26	
27	

Rainfall record of the Signal Service and Weather Bureau, San Francisco, beginning March 1, 1871—Continued.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1892.	*Inches.*	1893.	*Inches.*	1893.	*Inches.*	1894.	*Inches.*
Jan. 30	0.01	Feb. 1	0.03	Dec. 26	0.23	Dec. 4	0.56
31	.01	2	.19	27	.06	5	.60
Feb. 1	.30	3	.09			6	.23
4	.34	4	.57	1894.		7	.83
6	.39	5	.28			8	.87
17	.04	6	.04	Jan. 1	.23	10	.23
18	1.03	8	.36	2	.40	15	.10
19	.71	9	1.06	3	.01	16	.01
20	.05	12	.13	7	Trace.	17	.21
21	.01	Mar. 4	.94	8	Trace.	18	.99
24	.03	5	.10	14	.04	19	1.21
Mar. 1	.26	7	Trace.	15	1.84	20	.14
2	.16	8	.59	16	.08	21	1.19
15	.45	10	.08	17	.22	22	.16
18	.47	11	.98	18	.15	23	Trace.
19	.22	12	.04	19	.02	27	.30
20	.06	14	.01	20	2.61	28	.39
22	.01	15	.10	21	.16	29	.87
23	.01	16	.05	22	.17	30	.02
27	.29	18	.06	29	.05	31	.87
29	.72	19	.36	30	.01		
30	.20	20	.52	Feb. 5	.50	1895.	
Apr. 1	.26	21	.15	7	.09		
2	.02	23	.07	8	.03	Jan. 3	Trace.
14	.18	24	.02	9	.07	4	1.96
15	.05	29	Trace.	10	.14	5	.15
17	.06	30	.01	11	.01	6	.06
21	.38	Apr. 2	Trace.	12	Trace.	8	.82
22	Trace.	3	Trace.	15	.38	9	.01
24	.08	5	.23	16	.05	13	.45
29	.26	6	.49	17	.10	16	1.40
30	.10	7	.01	18	.14	17	.61
May 1	.19	8	.03	19	.85	18	.44
2	.07	9	Trace.	20	.33	19	.11
4	.01	10	.10	Mar. 2	.34	20	Trace.
5	.02	11	.04	5	.08	21	.32
6	.32	22	.13	6	.10	22	.63
7	.02	24	Trace.	7	.02	23	.03
10	.08	27	Trace.	8	Trace.	Feb. 10	.06
15	1.15	May 1	Trace.	9	.02	11	.96
June 12	Trace.	2	Trace.	16	.04	12	.91
13	Trace.	3	Trace.	18	Trace.	13	.10
Sept. 29	.02	8	Trace.	27	Trace.	21	Trace.
Oct. 6	.05	15	Trace.	29	Trace.	22	.19
9	.26	16	.04	30	Trace.	23	.09
16	.91	17	.11	Apr. 22	.01	Mar. 11	Trace.
27	Trace.	20	Trace.	23	Trace.	12	Trace.
28	.02	June 9	Trace.	25	.19	13	.02
30	.33	22	.03	26	.27	14	.01
31	.08	July 26	.02	27	.03	16	Trace.
Nov. 23	.35	Sept. 6	.02	May 14	.29	17	.10
25	.31	8	.07	15	Trace.	18	.05
26	.05	10	Trace.	20	Trace.	20	.67
27	.88	11	.12	21	.12	21	.04
28	.62	Oct. 9	.10	25	.63	22	.20
29	.39	15	.02	26	.05	26	Trace.
30	1.31	30	.04	27	.21	27	.35
Dec. 1	.06	Nov. 5	.02	31	.01	28	.45
2	1.22	6	.10	June 1	Trace.	Apr. 1	.01
3	1.30	7	.01	2	.20	10	.02
4	.18	21	.03	3	.02	13	.09
20	.01	22	.01	4	.17	24	Trace.
22	.04	23	.06	16	.15	25	Trace.
23	.26	24	1.26	17	.02	26	.37
24	1.14	25	.03	July 10	Trace.	27	.54
25	.57	26	1.69	Sept. 29	.68	28	.21
26	.30	27	.37	30	.87	May 1	.26
27	Trace.	28	.09	Oct. 17	Trace.	2	.01
		29	.30	18	.58	3	Trace.
1893.		30	.21	19	.02	4	.04
		Dec. 1	Trace.	20	.45	5	Trace.
Jan. 14	Trace.	13	Trace.	21	.04	6	Trace.
15	.27	14	.50	23	.64	25	Trace.
16	.05	21	.97	Nov. 26	Trace.	26	.14
26	.66	22	.04	27	.88	27	.07
27	.64	23	.01	Dec. 1	.03	28	.08
28	.04	24	.43	2	.18	July 1	Trace.
30	1.39	25	.01	3	.02	4	Trace.

Rainfall record of the Signal Service and Weather Bureau, San Francisco, beginning March 1, 1871—Continued.

Date.	Rainfall.
1895.	*Inches.*
July 5	0.01
Sept. 3	Trace.
9	Trace.
10	.09
11	.09
12	.56
13	.03
Oct. 15	.06
16	.01
19	Trace.
20	.01
21	.03
Nov. 3	.19
4	.04
5	1.04
6	.02
10	Trace.
12	Trace.
27	.26
28	.12
29	.11
30	Trace.
Dec. 1	Trace.
5	.09
6	.11
15	.13
16	.02
17	.13
18	.01
19	.83
20	.27
21	.34
23	Trace.
24	Trace.
1896.	
Jan. 13	.56
14	.17
15	.28
16	.46
17	.98
18	1.18
19	.04
20	1.01
21	.21
23	.52
25	.68
26	.55
27	1.35
28	.15
Feb. 1	.18
21	.01
26	Trace.
27	.01
28	.05
29	.03
Mar. 2	.55
3	.45
4	.07
5	.25
6	.05
14	Trace.
15	.32
16	.74
19	Trace.
20	.03
21	.02
22	.10
23	.01
26	.16
27	.10
Apr. 5	.91
6	.53
9	.24
10	.06
12	Trace.
13	.02
1896.	*Inches.*
Apr. 14	0.09
15	.14
16	.01
19	Trace.
21	.22
22	.02
23	.69
24	1.90
25	.10
26	.13
29	.09
May 1	Trace.
3	Trace.
4	.04
5	Trace.
7	Trace.
11	.27
20	Trace.
21	.33
22	.03
29	.05
30	Trace.
July 10	.04
24	Trace.
25	Trace.
Aug. 18	.01
19	.02
28	Trace.
30	.06
Sept. 15	.02
18	.01
19	.08
22	.40
23	.01
Oct. 10	Trace.
11	.01
24	Trace.
25	Trace.
26	.54
27	.94
29	.04
31	.02
Nov. 8	Trace.
9	.31
10	Trace.
11	Trace.
16	.01
17	.24
19	.14
20	.44
21	Trace.
22	.31
23	2.00
24	1.11
Dec. 12	Trace.
13	.28
14	.02
15	.07
16	1.65
17	Trace.
18	.02
19	Trace.
23	.02
24	Trace.
26	.53
27	.79
28	.11
29	Trace.
30	.56
31	.29
1897.	
Jan. 13	.01
14	Trace.
16	.03
20	Trace.
24	.06
1897.	*Inches.*
Jan. 25	Trace.
27	0.18
28	.09
29	.77
30	.04
31	1.08
Feb. 1	1.23
2	.04
3	.42
4	.66
5	.61
6	.01
7	.36
11	.02
12	.03
13	.17
14	.02
15	Trace.
16	.06
17	.01
18	.27
19	.39
20	.09
28	.01
Mar. 1	.38
2	.88
3	.36
4	Trace.
5	.27
6	.74
7	.15
8	.12
9	.01
16	Trace.
17	.04
18	.08
19	.03
20	.03
25	Trace.
27	.10
28	1.83
29	Trace.
31	.04
Apr. 1	.20
4	Trace.
6	.03
18	Trace.
19	.04
May 6	Trace.
13	Trace.
14	Trace.
15	Trace.
16	.02
17	.59
June 14	.03
19	.03
20	.16
21	Trace.
22	Trace.
24	Trace.
25	Trace.
26	Trace.
July 22	Trace.
Aug. 3	Trace.
9	Trace.
15	Trace.
Sept. 3	.02
25	Trace.
26	Trace.
28	Trace.
30	.08
Oct. 1	Trace.
5	Trace.
6	Trace.
12	Trace.
13	.01
21	.27
22	.01
1897.	*Inches.*
Oct. 23	1.41
Nov. 3	Trace.
4	.23
5	.01
6	.03
13	Trace.
14	.01
20	.11
23	.42
24	.22
25	.02
Dec. 6	Trace.
7	.75
8	.27
9	.01
10	Trace.
11	.07
14	.12
24	Trace.
1898.	
Jan. 6	.32
7	.03
8	Trace.
11	.31
12	.02
15	.25
16	Trace.
17	.09
19	.03
22	Trace.
24	Trace.
25	.07
31	Trace.
Feb. 1	.20
3	.02
5	.08
6	.17
7	.19
8	Trace.
12	.01
20	Trace.
21	.44
24	.78
25	.02
26	.01
27	.21
Mar. 7	.05
8	.08
14	Trace.
15	.04
16	.03
17	Trace.
25	.04
Apr. 2	Trace.
6	.19
May 1	Trace.
4	Trace.
5	Trace.
12	Trace.
13	.03
14	.35
15	.89
16	.04
21	.01
22	.06
26	Trace.
27	.03
28	.03
31	Trace.
June 1	.18
8	Trace.
9	.01
10	Trace.
11	Trace.
Aug. 2	Trace.
3	Trace.

Rainfall record of the Signal Service and Weather Bureau, San Francisco, beginning March 1, 1871—Concluded.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
1898.		1898.		1899.		1899.	
	Inches.		*Inches.*		*Inches.*		*Inches.*
Sept. 22......	0.09	Dec. 20......	0.32	Feb. 2......	Trace.	Apr. 2......	Trace.
24......	Trace.	29......	.01	3......	0.02	18......	Trace.
25......	.73			28......	Trace.	23......	0.03
26......	.24	1899.		Mar. 1......	.22	24......	.45
Oct. 2......	.24			2......	.01	25......	.05
6......	Trace.	Jan. 1......	.47	8......	.02	27......	.03
7......	.45	2......	.22	9......	Trace.	30......	.06
9......	Trace.	3......	.03	11......	.01	May 22......	Trace.
22......	Trace.	6......	.03	14......	.21	24......	.10
23......	.12	7......	.93	15......	.95	29......	Trace.
30......	Trace.	9......	.22	16......	.93	31......	.76
31......	.05	10......	.78	19......	.38	June 1......	.01
Nov. 19......	.24	11......	.27	20......	.23	19......	Trace.
20......	.12	12......	Trace.	21......	.11	24......	Trace.
22......	.04	13......	.22	22......	2.15	26......	Trace.
28......	Trace.	14......	.21	23......	1.48	Aug. 7......	Trace.
29......	.06	15......	.29	24......	.87	11......	Trace.
Dec. 13......	Trace.	16......	Trace.	25......	.01		
14......	.59	17......	Trace.	28......	Trace.		
19......	.70	Feb. 1......	.08	29......	.03		

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Bulletin No. 29.—W. B. No. 219.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

FROST FIGHTIN

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bu

BY

ALEXANDER G. McADIE,

FORECAST OFFICIAL.

WASHINGTON:
WEATHER BUREAU.
1900.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., March 13, 1900.

Hon. JAMES WILSON,
Secretary of Agriculture, Washington, D. C.

SIR: I have the honor to submit herewith a brief paper on "Frost Fighting," by Mr. Alexander G. McAdie, forecast official, who has devoted much attention to the subject. While the Bureau has but recently issued a bulletin on the same subject, it is believed that the more recent experiments with which Mr. McAdie deals are sufficiently valuable to the extensive fruit interests of California to justify the printing of an edition of five thousand primarily for that State. I therefore recommend the publication of the paper as a bulletin of the Weather Bureau.

Very respectfully,

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

Approved:
JAMES WILSON,
Secretary.

ILLUSTRATIONS.

Fig. 1.—Composite barometric and thermometric conditions followed by heavy or killing frosts within twelve hours.

2.—Relief map showing extreme minimum temperatures during frosts injurious to citrus fruits.

3.—Wire baskets in citrus grove.

4.—Wire baskets hung from limbs of orange trees.

5.—Wire baskets in lemon and orange grove.

6.—Mr. Priestly Hall's device for smudging.

7.—Eight miners' inches of warm water in orange grove at Meacham Ranch.

8.—Lath screen at ranch of Mr. A. J. Everest, Riverside, Cal. (view from above).

9.—Lath screen at ranch of Mr. A. J. Everest, Riverside, Cal. (under view).

FROST FIGHTING.

For the past four years the Weather Bureau office at San Francisco has given much attention to the question of protecting the citrus fruit crops of California, particularly of the section south of the Tehachapi, from frosts. It has been estimated that the value of the citrus fruit crop for this section during the year 1899 was in the neighborhood of $7,000,000. It will be readily seen that even if so low a proportion as five per centum of the crop should be lost through frost, the amount involved is still so considerable as to warrant a systematic study of the problem and an endeavor to devise methods minimizing this loss. The problem is of a twofold nature; first, accurate forecasting of the frost period; second, efficient methods of raising the temperature at critical times. The Weather Bureau office at San Francisco has demonstrated beyond criticism that frost can be successfully forecast. Certain fruit growers, and particular credit should be given to the Riverside Horticultural Club for its work in this direction, have both devised and tested methods of smudging, irrigating, heating, covering, etc., of great practical value.

The experience of the past three years warrants the statement that the loss due to frosts in California, hitherto considered unavoidable, can be prevented, and that unless extreme conditions, by which is meant lower temperatures by 5° than have ever yet been experienced in this State, occur, the citrus fruits of California can be successfully carried through the period when frost is likely.

It should be noted at the outset that in many sections for some years past, it has been the practice to call certain areas frostless. Many of the foot-hill sections are advertised as regions in which frost has never been known to occur, but such statements must be received with caution and reliable records insisted upon. For reasons which will be given later in connection with the matter of "Air Drainage," it is plain that places which are exempt from frost one season may be visited with frost at another time and that a slight shifting of the lower air currents is responsible for much of the *streakiness* so characteristic of frost. The surface drainage of the air is not a fixed condition and consequently a region which is frost free under some conditions may be visited with frost when these conditions are slightly altered. In general, then, no section in districts where frost does occur is to be considered as frost proof.

The chief result of the work in California during the past four years is the establishment of the principle that *the formation of frost* *is primarily a matter of air drainage.* This principle is shown both in the general pressure distribution over the southwest portion of the country during frost periods, and on a smaller scale in the motion of the surface air currents in certain small areas. A composite map showing the conditions preceding frost was prepared in December, 1899 (see fig. 1[1]). A relief map (see fig. 2) of southern California used in connection with the pressure map will show that the air moving from the north through El Cajon Pass, or over the San Bernardino Mountains, drains southwestward into the districts which are the center of the citrus fruit industry in southern California. When this cold, dry air settles in these lower lands, the temperature near the ground about the time of sunrise will range from 22° to 32°. An important relation, first pointed out by Prof. W. H. Hammon, for forecasting frosts for southern California is this: A wave of falling pressure passes from Montana or Idaho southward across Utah and westward through southern Nevada, thence into Arizona or southern California, and if followed by a rapid rise in pressure, is generally the forerunner of much colder weather in the southern citrus belt. In other words, the usual warm lower air strata are vigorously displaced by cold, dry air; and when the draining ceases and the cold air settles during the period of comparative stillness, frost forms. What is true on a large scale is true on a smaller scale, and a close agreement exists between frost belts or frost streaks and areas of stagnant, cold air. An attempt has been made to plot the channels of air motion and the frost streaks in certain districts. Mr. Frank H. Olmstead, acting for the Los Angeles Daily Times, surveyed the frost localities in Los Angeles, Riverside, San Bernardino, and Orange counties. The survey was necessarily a hurried one; but the correlation of frost streaks and stagnant air was evident. A careful survey should be made by every ranch owner. The writer has urged this matter believing that each grower must work out his own salvation, and that besides studying and practising methods of protection, it is necessary to be familiar with the air drainage of the ranch. In nearly every ranch that the writer has visited there have been certain well-marked cold spots which, in most cases, were found to correspond with slight depressions in the ground. These three deductions can be drawn from what precedes: (1) Where the air is in brisk motion damage from frost is generally light. (2) ~~Stagnant~~ air, such as exists in low valleys, basins, and inclosed areas, favors frost. (3) As the coldest layer is generally near the ground, it is sometimes advisable to drain downward upper, warm air, displacing surface layers.

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[1] The map shown by fig. 1 is a composite of many dates which were followed by heavy or killing frosts within twelve hours. It should be studied carefully by orange growers; and from the beginning of December to the end of the frost season the daily weather maps issued at San Francisco and Los Angeles should be carefully compared with this map. In brief the condition preceding frost is the passage of a low area from Idaho southward across Utah, westward through southern Nevada, and southward into southern California, followed by a marked high. For the most part frosts are due to the movement of the cold air from the northeast. Frosts also occur when a low over southern California moves rapidly southeast, and is followed by a high from northern California. Conversely when air moves from the sea inland, i. e., when the breeze is from the south and west, there is little danger from frost.

In studying frost formation it must be remembered that if there is little aqueous vapor there will be but a small quantity of frost. The temperature of the air, however, may be sufficiently low to seriously injure vegetation. This explains why with low temperatures and low dew-points in certain regions, especially where the radiation of heat is very rapid during the night hours, there are no frosts. It is too dry. Conversely, high dew-points and much moisture in the air sometimes are followed with heavy frosts, although the air temperatures range between 40° and 45°. These points are mentioned to answer the questions which are often propounded, why with low temperatures there is no frost; or why there is no frost one morning and there is frost on a succeeding morning when the temperature is perhaps higher. Distinction must be made between the deposition of the moisture in the air and the temperature of the air itself.

METHODS OF PROTECTING.

Every fruit grower should put himself in communication with the nearest center of distribution of weather forecasts. If possible he should be in daily communication with some Weather Bureau office. Whenever frost warnings are issued for his locality he should carefully determine the temperature and dew-point, as elsewhere described, frequently during the late afternoon and night. A good outfit consists of a metallic thermometer so arranged as to automatically close an electric circuit and ring an alarm whenever the temperature of the air reaches 32°. In addition to a reliable sling psychrometer there should be some small device for testing the motion of the gentle air currents in the orchard. Too much attention can not be given to this question of air motion. Many smudging devices have failed to be effective because of a slow movement of the smoke away from the orchard.

PROTECTIVE METHODS BASED ON MIXING THE AIR.

It is well known that lowlands are visited with frost while hillsides and hilltops escape. Every fruit grower should study the topography of his land and plant accordingly. Wind-breaks are, as a rule, considered detrimental. No hard and fast rule, however, can be laid down. On a well-known lemon and orange ranch at Santa Paula, the property of Mr. N. W. Blanchard, there are several large wind-breaks which have proven themselves to be of the greatest ~~benefit in~~ protecting fruit from frost. It would almost seem as if the citrus trees within a distance of 50 feet were directly protected by these wind-breaks. By planting a wind-break in the proper place, defects in the topography may be overcome and air currents established where otherwise pools of quiet air would have formed. A wind-break dense enough and so situated as to interfere with any natural circulation and facilitating the formation of still areas or pools would, of course, prove injurious.

PROTECTIVE METHODS BASED ON WARMING THE AIR.

A large number of small fires, advantageously placed, will raise the temperature of the air several degrees. The Riverside Horticultural Club, testing the various methods which were in use in California, came to the conclusion that wire baskets suspended a few feet above the ground, and holding several pounds of coal or charcoal, made an efficient protector. This method was described by Mr. Edward Copely, of Riverside, Cal., in several articles published in the Riverside Press of April, 1896. The cost of the wire basket is about ten cents, and if forty baskets be used to the acre, the cost of fuel will hardly exceed $2.50. To this must be added the cost of labor during the night and succeeding day in refilling the baskets. In the accompanying figures, Nos. 3, 4, and 5, the baskets are shown in position. This method meets with most favor in southern California. The temperature can be raised certainly 3° or 4° with from twenty to forty of these baskets to the acre. It has been suggested that a number of small oil lamps be used with success for this purpose. Oil pots have been used and make a hotter fire, but the deposit of lamp black upon the fruit is objectionable. Some cheap modification of the ordinary plumber's furnace might possibly be devised which, by means of a moderate blast, would produce a high temperature.

PROTECTIVE METHODS BASED ON CLOUD OR FOG BUILDING.

Damp straw, old wood, prunings, manure, etc., when burned briskly furnish an effective smoke, and if the material while burning is doused with water, the result is a dense steamy smoke, which, while trying on human lungs, serves as a screen to prevent loss of heat by radiation and as a barrier between the chilled fruit and a sudden application of heat at the time of sunrise. Wet smudging has been tried in many ways with varying results. There are many reports of failure, and on the other hand, some definite results, showing the good accomplished by this method. Here, as in all other methods of protection, much will depend upon a careful study of the local conditions. Many a farmer smudges so that some neighbor gets the benefit of his work while his own fruit remains unprotected. All motion of the air should be noted carefully, and this is sometimes difficult where the smoke is very dense. In some orchards sacks of old straw soaked with oil are so distributed as to be available for quick lighting. Portable smudges have also been devised. Fig. 6 illustrates a portable device by Mr. Priestly Hall.

Mr. Hall has made an efficient form of sled operating under the wet smudge principle. Upon a sheet iron sled he has placed a small fire box, consisting of a grate 4 or 5 inches above the bed of the sled, over which pass iron rods bent in the form of an arch, leaving a space for the fire about 14 inches in diameter. This fire box is inclosed in a large corrugated iron box, which has the bed of the sled (about 3 or 4 feet in size) for a bottom, and sides 30 inches high. A door is made in front of the corrugated box to admit fuel to the fire. The box is filled with wet straw or manure and a fire is maintained in the fire box when the machine is in operation. The cost is about $12; one will do for ten acres.

PROTECTIVE METHODS BASED ON IRRIGATION.

Of all methods proposed for the protection of fruit, excepting wire baskets, irrigation has the largest amount of evidence in its favor. It has been tried in many different places with different crops and has generally given satisfaction. Where water is not very plentiful, and this is the case strangely enough in some fruit sections, the method may not always be practicable, but with this exception there are many decided advantages in the generous use of water. Injury from frost depends almost as much upon the condition of the tree as upon the severity of the weather. Critical periods in the life of the tree can be controlled to some degree by the use of water.

Some fruit growers hold that heat is the one thing that is desired at times of frost, and that the best method is that which produces heat by the simplest and least expensive process. Water, owing to its high specific heat, forms an excellent agency for the temporary storage of heat energy. We have seen that in the wet smudge an attempt is made to utilize the latent heat of vaporization, and theoretically this has always seemed the most advantageous method. A modification of the wet smudge is steam piped through an orchard. This experiment was made by the Wright Brothers at Riverside, Cal., with a 35-horsepower boiler and a main pipe 2 inches in diameter, from which, at right angles every 40 feet, pipes three-quarters of an inch in diameter were extended. It is claimed that the temperature was raised 3° whenever the steam was turned on. It is also said that the coal consumed would not be more than the amount used by the basket method. The estimated expense per acre would be about $75.

The latest device for the protection of citrus fruit against frost combines the good effects of irrigation with heating. This is a method known as the warm water method, tried at Riverside this year. An account of the experiment follows:

Experiment of Mr. Ernest A. Meacham, Riverside, Cal.

On the morning of February 9, 1900, at the Meacham Ranch, a test was made of the Meacham warm water method of protecting citrus fruits against frost. The experiment began at 3:45 a. m., and was conducted in the presence of a number of gentlemen belonging to the Riverside Horticultural Club, nearly all of whom were orange growers.

At 6:30 a. m. the temperature of the ground 100 feet or more away from the boiler was 32°. The temperatures given herewith are those obtained by Mr. McAdie of the Weather Bureau with sling psychrometer No. 70; the number of the dry thermometer was 4487 and of the wet 4486. The plant consists of a 12-horsepower tubular horizontal boiler, laid in a brick furnace, and arranged to deliver water with or without pressure. Cold water enters the bottom of the boiler and is delivered from the top orifice directly into the flume. The fuel used was crude petroleum, of which about 50 gallons were used in three and one-half hours. At the rate of 14 gallons an hour and an estimated cost of a little over 4 cents per gallon, the actual expense of fuel for the experiment was about 60 cents per hour. The oil is burned with a steam jet under pressure. A secondary 6-horsepower boiler, carrying 70 pounds of steam, was used. The oil is thus entirely consumed and makes but little smoke. The whole arrangement is such that not more than two men would be required to attend to all the details.

Fifty minutes from the time of beginning, the water which had an initial temperature of 55.4° was raised 30°. Two sets of temperature records were made, one by Mr. Priestley Hall and the other by Mr. McAdie. In Mr. Hall's test 8 inches of water was run in fifty furrows, which barely ran the water past the ends of the furrows. In the second case 8 miners' inches of water was delivered into twenty-five furrows, thus carrying the heat farther down the furrows than in the first experiment. According to the present laws of California, a miners' inch is $\frac{1}{50}$ cubic foot per second; the second foot is the quantity represented by a stream 1 foot wide and 1 foot deep, flowing at the average rate of 1 foot per second. A cubic foot of water, maximum density, weighs 62.4 pounds; a gallon contains 10 pounds of distilled water at 62°. The data obtained by Mr. Hall were as follows: 5:30 a. m., normal temperature, 34°; normal temperature of water, 60°; temperature of heated water, 92°; at the flume, 92°; 20 rods from the flume, 58°; 40 rods, 52°; temperature of unheated water 40 rods from the flume, 41.5°; vapor condensed on trees early in the morning and more condensed on the trees in the heated plat.

Mr. McAdie's records are as follows: Time, 6:30 a. m., air temperature varying from 34° to 36°; temperature on the ground, 32°; frost was observed on grass blades; initial temperature of water, 55.4°; heated water delivered to flume at 85.2°; in a straight line down a furrow 200 feet from the boiler in the direction of the wind (motion of the air was very gentle) there was a fall in temperature of 14.2°; water vapor was observed rising to a height of about 4 feet; 200 feet from flume, as stated, the temperature of the water was 71°; the temperature of the surface soil 4 inches right and left of the water was 43°; temperature of the soil 16 inches from the water or in the middle of the ridge, 42.2°. It is presumed that the temperature of the ground had no water been flowing would have been 33°, and it would seem as if the soil itself was warmer by nearly 10°. At the end of a furrow, 660 feet, the temperature of the water was 54°, or there had been a fall of 31° in 40 rods; the temperature of the ground 4 inches from the water, 38°; 16 inches from the water, 36°; temperature of unheated water 50 rods from the flume, 40°.

The approximate value of the plant was $200, and it is estimated that for a plant all equipped sufficient for a ten-acre grove $600 would cover all expenses. See fig. 7.

SPRAYING.

After frost, or rather just before a frost has ended, a spraying device can be used to advantage. Its chief function is to prevent a too rapid warming of the chilled fruit. It is said by horticulturists that even the light coating of ice formed in this way does not seriously damage the fruit. It is very likely that the latent heat of solidification set free by the change from water to ice may play a helpful part; but the chief effect is to prevent a too rapid thawing. In other words, both heat and water should be supplied to the chilled plant slowly, and according to the plant's ability to make good use of the same. At the A. J. Everest ranch at Riverside, Cal., a portion of the grove is protected by sprinklers at the top of fifty-foot masts.

PROTECTIVE METHODS BASED UPON SCREENING OR COVERING.

All screening or covering devices are in effect modified hothouses, and there is no question but that a thorough protection can be accomplished. The expense is the one objection. Screens are made of light materials, namely, canvas, muslin, or light wood work, and have been used with considerable success. At the A. J. Everest ranch an elaborate structure of lath screens is in use, illustrations of which are given herewith (see figs. 8 and 9). There is no question as to the value of the protection, but the expense is considerable, averaging perhaps $400 to the acre. This lath covering may be considered as forming a well ventilated hothouse.

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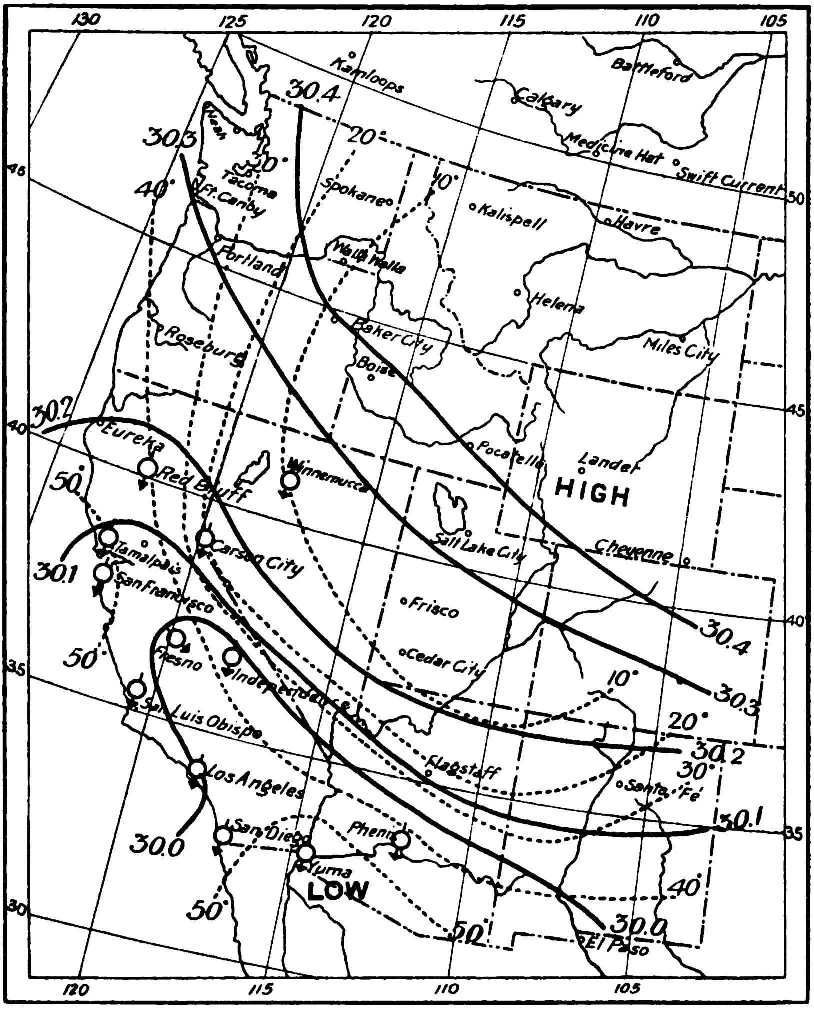

Fig. 1. Composite barometric and thermometric conditions followed by heavy or killing frosts within twelve hours.

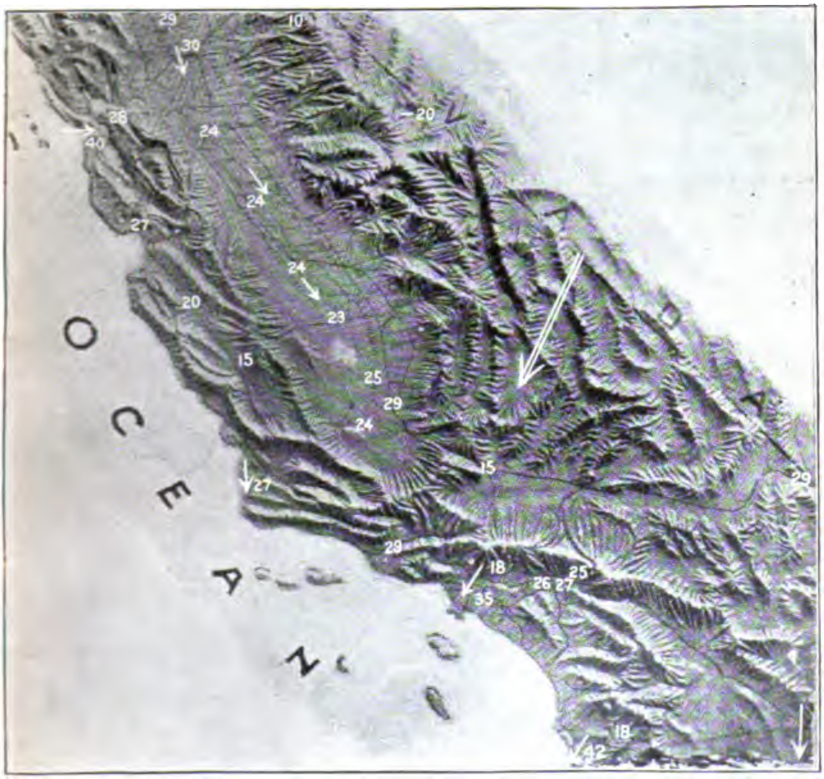

FIG. 2. Relief map showing extreme minimum temperatures during frosts injurious to citrus fruits.

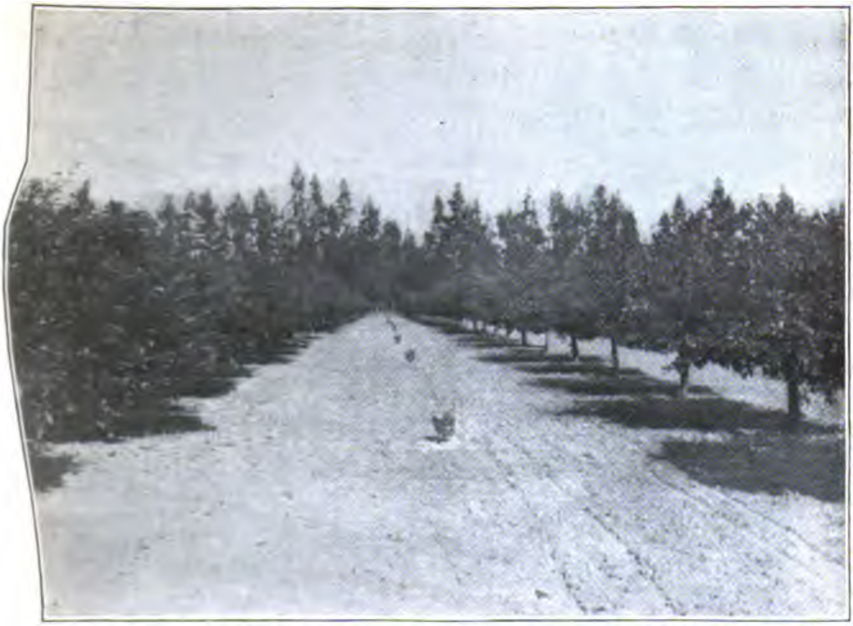

Fig. 3. Wire baskets in citrus grove.

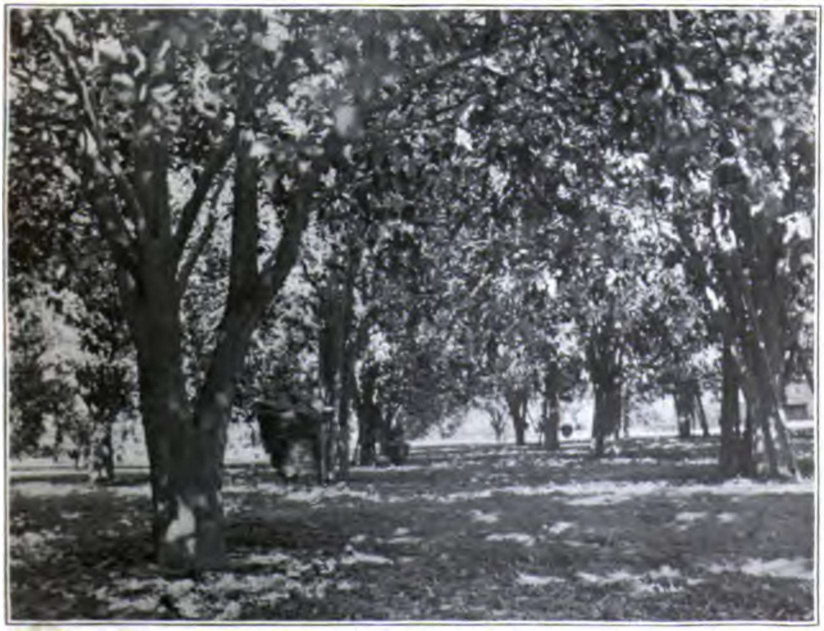

Fig. 4. Wire baskets hung from limbs of orange trees.

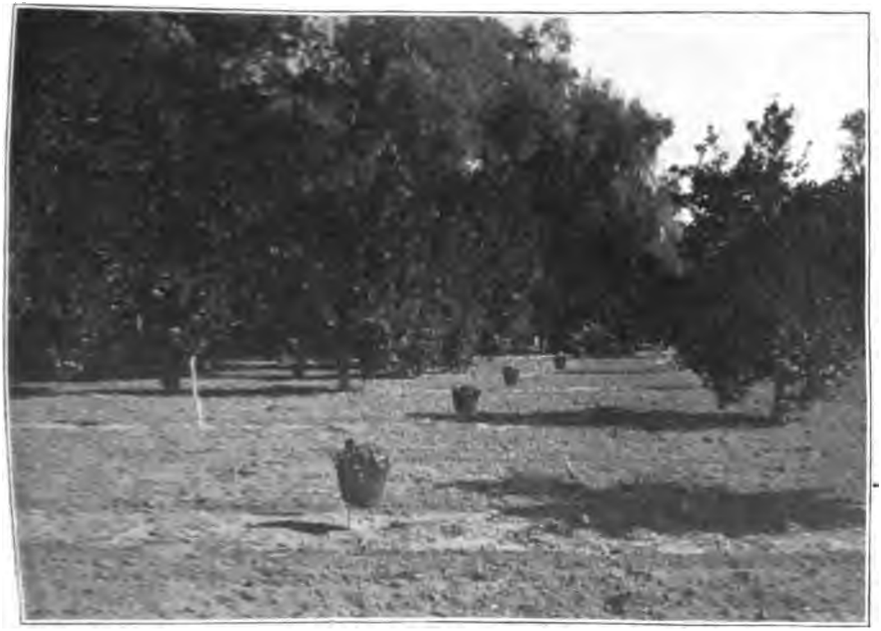

Fig. 5. Wire baskets in lemon and orange grove.

Fig. 6. Mr. Priestly Hall's device for smudging.

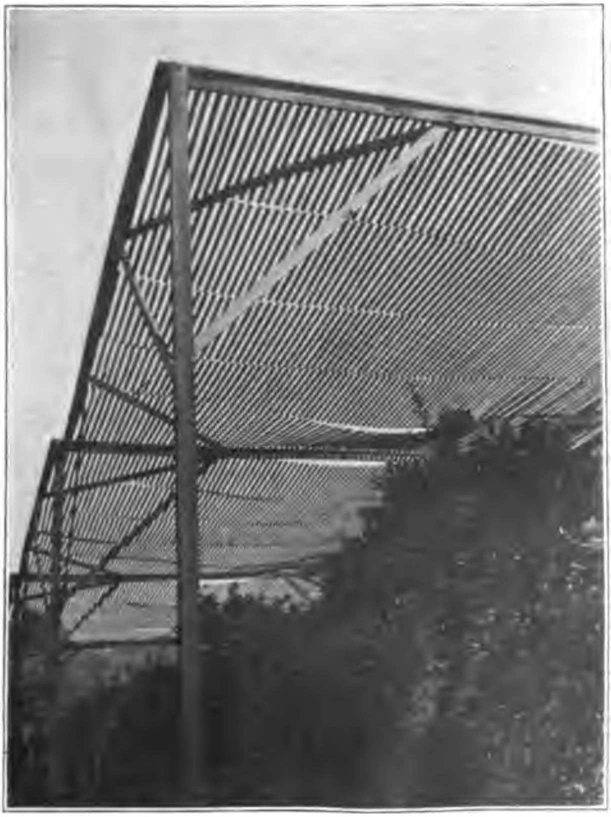

Fig. 9. Lath screen at ranch of Mr. A. J. Everest, Riverside, Cal. (under view).

BULLETIN No. 30. W. B. No. 256 **Price 10 Cents.**

U. S. DEPARTMENT OF AGRICULTURE.

WEATHER BUREAU.

LOSS OF LIFE IN THE UNITED STATES BY LIGHTNING.

Prepared under the direction of WILLIS L. MOORE, Chief U. S. Weather Bureau,

BY

udson

ALFRED J. HENRY,

PROFESSOR OF METEOROLOGY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1901.

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BY

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U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., December 3, 1901.

Hon. JAMES WILSON,
Secretary of Agriculture.

SIR: I have the honor to transmit herewith a paper by Alfred J. Henry, professor of meteorology, entitled Loss of Life in the United States by Lightning, and to recommend its publication as a bulletin of the Weather Bureau.

The aim of the paper is to furnish accurate information as to the destruction of human life annually by lightning; to point out the regions where the greatest loss of life occurs; and, so far as practicable, to call attention to the few simple precautions against danger that may be exercised by the individual.

Very respectfully,

WILLIS L. MOORE,
Chief United States Weather Bureau.

Approved.
JAMES WILSON, *Secretary.*

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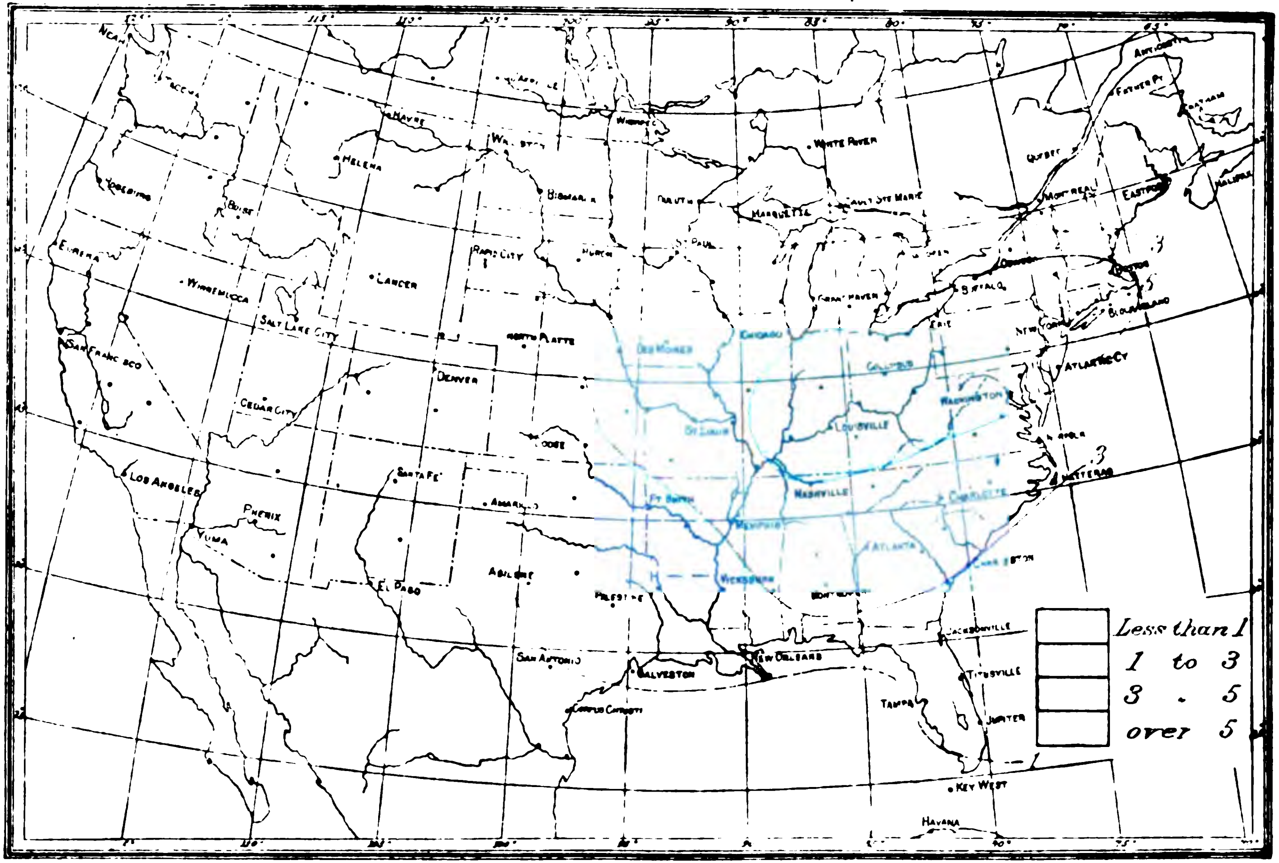
PLATE II. **Geographic distribution of deaths by lightning in the U. S.**

(Average number per unit area of 10,000 sq. mi.)



LOSS OF LIFE IN THE UNITED STATES BY LIGHTNING.

About a dozen years ago the opinion was expressed that more lives were lost by lightning than by violent winds and tornadoes. In order to determine as accurately as might be the number of fatalities from each of the two above-mentioned causes, a statistical inquiry was set on foot in 1890 and the inquiry has been maintained, so far as lightning is concerned, up to and including the calender year 1900. The number of fatal cases of lightning stroke was obtained at first by scanning four of the largest and most important newspapers in the country. At a later period the active cooperation of the officials in charge of Weather Bureau stations in the large cities was solicited; and, finally, in 1899, in order that there might be no reasonable doubt as to the accuracy of the statistics being thus collected, the aid of one of the largest clipping bureaus in New York City was invoked. The number of clippings received from the clipping bureau alone, during the two years 1899 and 1900, was nearly 30,000. In this large number taken from newspapers, representing all parts of the country, there were naturally many duplicates, the number depending somewhat upon the value of the clipping as a news item. In some cases as many as 50 clippings were received, all of which referred to the same event although published on different dates and in different newspapers. The very great labor involved in identifying and classifying the thousands of clippings received annually, and the conviction that no useful purpose would be served by the further collection of such bald facts as are usually contained in a newspaper narrative of lightning phenomena, led to the abandonment of the work at the close of 1900.

The inquiry was begun in 1890 and has, therefore, extended over eleven years; it is now known that the results for the earlier years are incomplete and the reason is not far to seek. The greatest number of fatalities occur in rural districts some distance from telegraph and telephone lines, and the great news centers. The death of the victim is generally chronicled in the county paper, but rarely in press dispatches and the larger dailies. Some of the large daily papers of the Middle West contain much information concerning deaths by storm and lightning throughout the Mississippi and Missouri valleys and the

Southwest, yet their correspondents can cover at best but a relatively small proportion of that great domain. In the older and more densely populated Middle Atlantic districts the information at hand is much more complete; yet, after all, it is only when every county paper in the land has been carefully scanned that we may feel assured that our results are, at least, approximately correct.

It is the particular sphere of the county newspaper to chronicle events happening within the geographic boundaries of its constituency and, moreover, unlike the daily newspaper, it is not deterred from publishing an item merely because the event happened a fortnight ago. The earlier statistics of loss of life and property by lightning are defective because the county newspapers were not examined. Our present knowledge of the death rate by lightning would be greatly increased if all local and State boards of health would segregate deaths due to lightning from deaths due to other causes, as is now done in some States, notably Minnesota, Michigan, Massachusetts, and a few others.

The number of persons killed by lightning during 1900 is given by months and States in Table I, the number injured in Table II. Seven hundred and thirteen persons were killed or received fatal injuries during the year. Of this number 291 persons were killed in the open, 158 in houses, 57 under trees, and 56 in barns. The circumstances attending the death of the remaining 151 are not known. Nine hundred and seventy-three persons were more or less injured by lightning stroke during the year. Of this number 327 persons received their injuries while in houses, 243 in the open, 57 in barns, and 29 under trees. The circumstances attending the injury of the remaining 317 cases are not known.

The foregoing statements briefly sum up the net results of the ravages by lightning in a single year. The summary itself tells little, nor can it, of the infinite variety of external circumstances attending the destruction of so many people. Some were stricken in their homes, some on the highways, some in the field or barn, and some while seeking temporary shelter under trees. It has been pointed out again and again that it is not safe to take refuge from a thunderstorm under a tree. Doubtless most of those who perished while under trees would be alive to-day had they remained in the open. It is also injudicious to huddle under thrashing machines, sheds, or in the so-called "grand stands" pertaining to race tracks or county fairs, especially under or near the flagstaff. Men, like animals, are killed not singly, but in bunches when they huddle together.

The record of death by months for the eleven years, 1890–1900, appears in Table III. The most striking feature of that table is the great apparent increase in the number of deaths in 1899 and 1900. As before stated, however, the means adopted to ascertain the casualties in those years were very much more complete and extensive than had been previously used.

The writer has had personal cognizance of the methods in vogue from the beginning of the inquiry in 1890 until it was closed in 1900. It is his belief that the statistics (1899 and 1900) express very nearly the actual loss by lightning in the United States annually. The number may and probably does vary as much as 10 per cent above or below the average of those years, but it may be accepted as a fact, developed by this inquiry, that from 700 to 800 lives are lost each year by lightning stroke.

In a previous paper on this subject (Bulletin No. 26, Lightning and the Electricity of the Air, A. G. McAdie and Alfred J. Henry) the writer had occasion to discuss the relative frequency of fatalities by lightning in the several States and Territories. At that time, since the statistics covered but three years, it was thought inexpedient to attempt to draw conclusions from them. The addition of the very complete data for the years 1899 and 1900 to the previous record makes it possible to form some idea of the death rate due to lightning in the various States and Territories. It is obvious that the number of fatalities must depend partly upon the frequency of lightning strokes per unit area, partly upon the density of population, and partly upon the character of the thunderstorms which traverse the region. In the United States, thunderstorms occur with considerable frequency over all of the territory east of the one hundredth meridian, save a narrow strip along the northern border. West of the above-named meridian, except in the Rocky Mountain region, the frequency steadily diminishes, reaching practically zero along the immediate Pacific coast. There are three regions of maximum thunderstorm frequency, viz, one in the southeast, with its crest over Florida, one in the Middle Mississippi Valley, and one in the Middle Missouri Valley. (See Plate I.) The average number of days annually with thunderstorms in the first-named region is 45; in the second, 35, and in the last, 30.

Table IV has been constructed to show the average mortality according to geographic districts, subject approximately to the same or nearly the same atmospheric conditions. The nature of the data in the several columns is shown with sufficient clearness by the headings.

The greatest number of fatal cases, according to the figures in column 3, occurred in the Middle Atlantic States, and the next greatest in the Ohio Valley and Tennessee, with the Middle and Upper Mississippi Valley a close third. The greatest number of deaths in any single State during the five years, 1896–1900, occurred in Pennsylvania—186—followed by Ohio with 135, and Indiana, Illinois, and New York with 124 each.

The greatest fatality from a single stroke occurred at Chicago, Ill., where 11 persons, huddled together in a zinc-lined shanty under a North Shore pier, met instant death by a single bolt.

The chance of being struck by lightning evidently depends, as before stated, upon the frequency of lightning stroke per unit area; the total number of cases upon both the frequency of lightning stroke and the density of population. It is evident that the number of lightning strokes which fall in any State in a year, other things being equal, must depend upon the area of the State. It is also evident that the number of casualties will be greater the greater the number of persons exposed to effects of thunderstorm action. Accordingly the casualties have been classed under three different heads: First, in column 4, as the rate per million of rural population; second, in column 5, as the rate per million of total population; and finally, in column 6, as the average number per unit area of 10,000 square miles.

Some interesting comparisons may be made from these figures; thus, in the Gulf States, the average number of deaths due to lightning per unit area is but 1, although the average thunderstorm frequency is quite high. In New England, with probably only half as many thunderstorms, the death rate per unit area is 2. There being no large cities in the South, the rate per million of rural population and total population is practically the same, viz, 6 and 5 in the Gulf States, and 9 and 8, respectively, in the South Atlantic States.

The belief that the chance of injury by lightning in the cities is less than in the country is rather general. What foundation, in fact, such a belief has is hard to determine. It is not sufficient to show simply that a given area in any city is free from lightning stroke. It must be shown that an equal area outside of the city is subject to lightning stroke. When the combined area of the large cities is compared with the immense territory embraced in the rural districts it is not surprising that so few lightning strokes fall in cities. The modern city building, with its metallic roof and steel frame, is a fairly good conductor of electricity, and is in much less danger of receiving a damaging stroke of lightning than an isolated dwelling in the open country. The multiplication of telegraph, telephone, and electric light wires in cities also adds to the effectiveness of silent discharges in relieving the electric tension during a thunderstorm; but should a cloud with a tremendous store of energy quickly approach, all of the wires in ten cities would not prevent it from discharging right and left until its store of energy had been dissipated.

In New England the death rate by lightning per million of rural inhabitants is nearly double that per million of total population, and the same holds true of the densely-populated districts of the Middle Atlantic States. The large urban population of New York reduces the rate per million of total population in that State to but three, whereas in the neighboring State of Pennsylvania it is six. Both States are subject to practically the same atmospheric conditions and have the same percentage of deaths by lightning, if rural population only be considered.

We should therefore infer that statistics of death by lightning based on total population are not comparable except for areas having about the same density of population.

The greatest mortality by lightning, considering both unit area and density of population, is in the Ohio Valley and the Middle Atlantic States; if, however, density of population only be considered, it is in the Upper Missouri Valley and the middle Rocky Mountain region. The record of deaths by lightning in the middle Rocky Mountain region is rather surprising, in view of the vast extent of territory involved, the diversified character of its topography, and the sparsity of its population. The very large mortality in the mountainous States of Colorado, Montana, and Wyoming, and in the two Dakotas should emphasize the necessity on the part of persons living in those States of taking all known precautions to avoid the danger of lightning stroke.

Plate II shows the geographic distribution of fatal cases of lightning stroke in the United States. The chart is based on the figures of column 6, Table IV. Broadly stated, these figures represent the average number of fatal cases annually per unit area of 10,000 square miles.

It has often been suggested that an extended system of experiments should be made by the Government with a view of making life and property more secure during thunderstorms. The answer to this lies in the obvious difficulty of experimenting with a force that is manifested on such a tremendous scale as that of lightning. It is true that a discharge can be produced in the laboratory which in some respects resembles the lightning flash. The modern alternating machine and the device of a transformer enable one to study the character of lightning much more successfully than is possible by means of the ordinary frictional electrical machine; but while discharges of high electromotive force and great quantity can be obtained, yet the lightning flash of a mile or more in length so far transcends, in the tremendous potential to which it is charged, anything that can be produced in the laboratory that it seems hopeless to expect any material aid from experiments in the latter.

We may, perhaps, better understand the phenomenon of a lightning flash by noting the similarity between it and the discharge of a Leyden jar. The Leyden jar, it may be remembered, consists of a glass jar, coated both inside and out with tin foil for about four-fifths of its height. The mouth is closed by a cork, through which passes a metallic rod, terminating above in a knob and connected below with the inner coating, usually by a chain depending from it. The two coatings of the jar obviously serve as collecting and condensing surfaces and form, in connection with the glass jar, what is known in electrical terminology as a condenser. The capacity of a conductor may be enormously increased by bringing near it another conductor connected with the earth. This process is called "condensation of electricity." If the inner coating of a Leyden jar be connected with an electrical machine and the outer with the earth, the former will acquire a positive and the latter a negative charge. If now a metallic rod be brought near the two surfaces of the jar a spark is obtained whose power depends on the potential of the inner coating and on its electrical capacity.

If the jar has not been charged beyond its capacity it will retain its charge, under favorable conditions, for many days. If, on the other hand, the inner coating has been too highly charged partial discharges, invisible except as a phosphorescent glow in the dark, will occur from the inner to the outer coating until equilibrium is restored. Again, if a jar be subjected to a sudden rush of electricity it will overflow, that is to say, sparks will pass along the glass from the inner coating up over the lip of the jar and down the other side to the outer coating. Thus, we have seen that the overcharge of a jar may be dissipated by weak, partial discharges and also by a true spark discharge of some violence. The analogy between these two forms of discharge and what occurs in nature may be better perceived when we consider the layer of cloud as one coating of the jar and the surface of the earth as the other, while the air between takes the place of the glass of the jar. The glass of the jar, or in fact any insulating substance between two charged surfaces, is called the dielectric, and it is in this dielectric of nonconducting air between the clouds and the earth that we live.

In ordinary fine weather the upper regions of the atmosphere are at a different potential from the earth, but the difference in potential or pressure, if we may use the last term, is not great enough to produce a discharge. The sparking distance is too great, and, as in the case of the Leyden jar, no discharge will take place so long as the electrical tension remains unchanged.

It is well known that certain conditions of temperature, atmospheric pressure, and moisture favor the development of thunderstorms. Under such conditions the potential difference between the clond on the one hand and the surface of the earth on the other is increased, not gradually and for some time in advance of the thunderstorm, but rather suddenly, and more often locally than simultaneously over a large extent of territory. The cloud serves as a condenser of enormous extent, as compared with those used in laboratory experiments, but, nevertheless, the amount of charged surface presented to the earth may not, in the case of summer thunderstorms, exceed a few square miles. We have then, following out the analogy between a Leyden jar and a flash of lightning, a few square miles of cloud as one coating of the jar, an equal area of land as the other with the air between subject to stress or tension. As in the case of the overcharged Leyden jar, the tension may be relieved by invisible or silent discharges from the top of every rock, building, tree, wire or other metallic object within the strained field, as well as from the undersurface of the cloud.

Discharges of this character may and do take place through the human body, especially on high mountain summits, where the discharge at times is so marked as to cause apprehenson for one's safety.

Up to a certain point the air is able to resist the stress in it due to the electrification of the cloud mass. Whenever the stress passes a certain limit, which may be called the breaking point, the air gives way; literally it is cracked from cloud to earth like a piece of glass as the bolt descends. While human foresight is able to say approximately when a flash will occur, it can not say where the air will give way first. The zone of danger is in general coequal with the area of the storm cloud, although it sometimes spreads out some distance in front of the storm cloud. Almost any upright object in this area is a better conductor than the air in which it stands. The wonder is therefore not that so many persons and objects are struck, but that so many escape.

The ability of an electric current to break down a core of nonconducting air depends upon its electro-motive force. A current of 10,000 volts will jump across a space of about half an inch of common air, and hence it has been concluded that a flash of lightning that extends from cloud to earth must have an electro-motive force of many millions of volts. Since many thunderstorm clouds are at least a mile above the earth, we must continue to marvel at the source of the tremendous energy involved in a single thunderstorm.

The underlying causes of the electrical manifestations in a thunderstorm have not yet been clearly defined. It is known, of course, that the normal electric field of fair weather becomes disturbed concomitantly with certain other changes in the meteorological conditions, but no such relation as that of cause and effect has as yet been discovered. It is also well known that certain conditions of heat, wind, and moisture are present in the formation of thunderstorms, and it is, therefore, suspected that motion of some sort, whether mechanical, as of the wind, causing friction between the air particles; or molecular, as when water vapor is condensed into a liquid, is in some way the antecedent of the disturbed condition of the normal electric field. That there is some connection between the condensation of aqueous vapor and the electrical state of the atmosphere seems quite probable, but just what the relation is does not yet appear. The writer has observed the transformation of a plain cumulus cloud into a thunderstorm on more than one occasion. Rain almost invariably began before there was any display of lightning whatever. The first manifestations of the latter were usually in the form of light thread-like discharges within the cloud, without audible thunder. As the rain increased and the wind freshened the electrical discharges became more marked. These observations, though quite fragmentary, evidently indicate that the electrical tension of the air is increased by precipitation.

The very interesting and suggestive experiments of Townsend, Wilson, and others in the Cavendish Laboratory, Cambridge (England), have shown among other things that an electrified gas possesses the remarkable property of producing a fog when admitted into a vessel containing aqueous vapor and this without any lowering of temperature, such as would be produced by the sudden expansion of the gas in the vessel in which the fog is produced.

The effect observed by the late Robert von Helmholtz, viz., that a light semitransparent cloud of steam issuing from the orifice of a vessel was darkened and rendered much more opaque by the discharge of electricity into it, points also to a connection of some sort between the condensation of water vapor and tne electrical state of the atmosphere. On the other hand, the atmosphere may become highly electrified and all of the outward signs may point to rain, yet no condensation takes place, whether from lack of moisture in the air or some other cause is not known. The following description of an electrical and dust storm, by the late Dr. J. C. Neal, director of the Oklahoma Agricultural and Mechanical College at Stillwater, was published in the Monthly Weather Review of January, 1895:

> During the morning of January 20 [1895] the sky was filled with cirrus clouds, very feathery and white. In the afternoon it became hazy, then dark, and looked like rain. Wind in puffs from the southwest. At nightfall the sky cleared, but somewhat hazy. At 8 p. m., seventy-fifth meridian time, the wind changed to the west, and a gale began; by 9 p. m. it was frightful. The dust passed along in columns fully 1,000 feet high; the wind rose to a speed of 35, then 45 miles per hour, with gusts reaching 55 miles; the temperature fell rapidly, and we saw for the first time (about 9 p. m.) flashes of light that apparently started from no particular place, but pervaded the dust everywhere. As long as the wind blew, till about 2 a. m., January 21, this free lightning was everywhere, but there was no noise whatever. It was a silent electrical storm. This morning the sky is clear and, except that the dirt is piled up over books, windows, and in all the house, no one would know what a fierce raging of wind and sky we had.

Somewhat similar storms have been observed in western Kansas, eastern Colorado, and probably elsewhere in the eastern foothills of the Rocky Mountains. Mr. T. B. Jennings, section director of the Kansas climate and crop service, reports that the western counties of that State are occasionally swept by windstorms, called by the plainsmen electrical storms, although no lightning is seen and the weather is generally clear. The winds in these storms are generally of great force and sweep over large areas. Persons exposed to them become so strongly charged with electricity that a spark will readily pass from their hands to a metal object.

Electrical displays, similar to that observed by Dr. Neal in the dry climate of the West, without rain, have been observed in the West Indies and the humid regions of the eastern part of the United States with rain; so far therefore as crude observations of this sort are concerned, the dependence of rain upon the electrical state of the atmosphere is not established.

The occurrence of thunderstorms in the United States is not limited to the warm season, although the great majority of such storms happens in the months of June, July, and August. Winter thunderstorms are not infrequent in the Gulf States, and occasionally extend northeastward along the Atlantic coast to Massachusetts. At the close of winter the region of most frequent thunderstorms is in the Lower Mississippi Valley. In the spring months the area of greatest frequency extends rapidly northward, overspreading the Upper and middle Mississippi and the Missouri valleys by the end of April. The rainy season of the Great Plains region and the northeastern Rocky Mountain Slope sets in about the end of April, and from that time to the middle or end of July thunderstorms are of frequent occurrence. The season of greatest thunderstorm frequency east of the Alleghenies, especially in New England, does not set in until about the 1st of July, but lasts well into September.

As stated on a previous page, there is not that accordance between the number of lives lost by lightning stroke in the different parts of the country and the number of thunderstorms which might be expected. The low percentage of deaths in the Gulf States and Florida, where the average number of thunderstorms is higher than elsewhere, may possibly be ascribed to two causes: First, the sparseness of the population; and, second, to the less violent character of the thunderstorms which prevail in that region. The writer is aware of the difficulty in proving satisfactorily that the thunderstorms of one region are more violent than those of another. There is lacking, first of all, a convenient standard whereby one storm may be compared with another. In the second place, the thunderstorms of any region differ greatly among themselves, considering only the electrical manifestations. It is customary among observers to record as a full-fledged thunderstorm any disturbance in which a single distinct peal of thunder is heard, and thus the record is composed of a large number of thunderstorms of varying intensity. A storm may consist of many brilliant though harmless discharges from one portion of the cloud to another or from one cloud to another cloud, but no discharges from cloud to earth. Again, the discharges may be few in number, but violent and destructive of life and property.

Following the classification of Mohn, thunderstorms may be divided into two kinds, viz, heat and cyclonic, although it is quite probable that the great majority are a combination of these two forms. A third class, viz, winter thunderstorms, is sometimes added. In the United States winter thunderstorms may be classed as cyclonic, since they are rarely observed, except in connection with a well-marked cyclonic storm. Heat thunderstorms, as well as cyclonic, depend principally upon a convectional overturning of the atmosphere. The unstable condition may result from local heating in moist, quiet air, not under the domination of either cyclonic or anticyclonic systems. Thunderstorms occurring under such conditions fall under the first head. Their sphere of action is generally limited and they die away at nightfall, reappearing the next day and for many days in succession in particularly favorable regions. The Florida Peninsula is advantageously conditioned with respect to the development of heat thunderstorms. So, also, are the many parks and valleys of Colorado and adjoining States in the Rocky Mountain region, where heat thunderstorms are of daily occurrence in the summer season.

Cyclonic thunderstorms, as the name indicates, occur in connection with cyclonic disturbances, which generally move in an easterly direction over the northern third of the United States east of the Rocky Mountains. These storms are not necessarily confined to the southeastern quadrant of the cyclone, as has been frequently stated. In the northeastern Rocky Mountain slope and the Upper Missouri Valley they occur most frequently in the northwest quadrant of the storm on the dividing line between the cool westerly and warm southerly winds. East of the Alleghenies they occur more frequently at the moment the center of the disturbance passes. They also occur along the Middle Atlantic coast when the center of the disturbance has reached the mouth of the St. Lawrence. Plate III shows the weather conditions under which thunderstorms developed in the rear of a cyclone over a narrow belt extending from Arkansas to New England. Some of the most violent thunderstorms occur when the pressure gradients are weak and the cyclonic circulation of the winds uncertain and ill defined. In fact, a well-defined storm with moderate gradients and fresh winds is detrimental to thunderstorm formation.

Returning now to the statement on a previous page respecting the violence of thunderstorms in different parts of the country, we would remark that the thunderstorms of the Gulf and South Atlantic States are largely due to more or less local convectional overturning. It is probable that less energy is expended in their formation than in the case of cyclonic thunderstorm of the more northern districts which lie directly in the path of cyclonic storms. In the last-named districts thunderstorm activity is more general and widespread. It continues into and sometimes through the night hours with unabated severity. The energy involved, both molecular and mechanical in the movement of a general disturbance, is clearly much greater than that of the local thunderstorms of the Gulf and South Atlantic States. The squall winds of northern thunderstorms are in most cases more severe than those of the South; but, unfortunately for our argument, the force of the wind is not always a measure of the electrical energy of the storm. It is true that destructive lightning strokes sometimes fall from storm-clouds that are not especially ominous or threatening; moreover, intense outbursts of electrical energy in connection with thunderstorms sometimes break out almost simultaneously over considerable areas without any decided antecedent storm movement. These violent outbursts seldom occur except along the path most frequented by cyclonic thunderstorms. This single fact, whatever be the cause, will largely account for the greater loss of life and property in the North and West as compared with the South.

Some situations are more dangerous than others during the prevalence of a thunderstorm. In what follows the reader is advised of the exposures that should be avoided.

Much of this matter is a reprint from Bulletin No. 26, Lightning and the Electricity of the Air.

It is not judicious to stand under or near trees during thunderstorms, in the doorway of barns, close to cattle, near chimneys and fire places, or near the terminus of a wire clothesline. Avoid suspending the latter between a corner of the house and a convenient tree, rather let it be hung from one tree or post to another. On the other hand, there is not much sense in going to bed or trying to insulate oneself in feather beds. Small articles of steel, also, do not have the power to attract lightning, as it is popularly put, or determine the path of discharge.

Just in advance of thunderstorms, whether because of the varying electrical potential of the air, or of the changing conditions of temperature, humidity, and pressure, and failure of the nervous organization to respond quickly, or to whatever cause it may be due, it can not be denied that there is in certain individuals much suffering from depression at these times. It is, perhaps, possible that these sufferings may be alleviated. Apart from this many people suffer greatly from alarm during the prevalence of thunderstorms, somewhat unnecessarily, it is thought. Grant even that the lightning is going to strike close in one's vicinity. There are many flashes that are of less intensity than we imagine, discharges that the human body could withstand without permanent serious effects. Voltaire's caustic witticism "that there are some great lords which it does not do to approach too closely, and lightning is one of these," needs a little revision in these days of high potential oscillatory currents. Indeed, the other saying, "Heaven has more thunders to alarm than thunderbolts to punish," has just so much more point to it, as it is nearer the truth. One who lives to see the lightning flash need not concern himself much about the possibility of personal injury from that flash.

Finally, if one should be in the vicinity of a person who has just been struck by lightning, no matter if the person struck appears to be dead, go to work at once and try to restore consciousness. There are many cases on record proving the wisdom of this course; and there is reason for believing that lightning often brings about suspended animation rather than somatic death. Try to stimulate the respiration and circulation. Do not cease in the effort to restore animation in less than one hour's time. For an excellent illustration of a case of severe lightning shock and recovery, due, it would seem, to prompt action by the medical gentlemen present, all who are interested may consult the Medical News, August 11, 1888. A number of cases corroborative of this view are on record in various medical journals.

No matter which method for respiration is used, it is important to maintain the warmth of the body by the application of hot flannels, bottles of hot water, hot bricks, warm clothing taken from bystanders, etc.

Firmly and energetically rub the limbs upward so as to force the blood to the heart and brain. If an assistant is present, let him attend to this. Remember above all things that nothing must interrupt your efforts to restore breathing.

When swallowing is established a teaspoonful of warm water, wine, diluted whisky or brandy, or warm coffee should be given. Sleep should be encouraged. In brief—

1. Make the subject breathe by artificially imitating the respiratory movements of the chest.
2. Keep body warm.
3. Send for a physician.

Of the visible effects of lightning stroke upon the human body little more can be said than that sometimes burns, usually superficial, have been noticed, frequently red lines or markings, which are localized congestions of the small blood vessels of the skin. These, from their irregularities and branchings, have led to the fanciful idea of photographs of trees, etc.

In conclusion, it may be said that lightning frequently causes a temporary paralysis of the respiration and heart beat, which if left alone will deepen into death, but intelligently treated will generally result in recovery.

TABLE I.—*Killed by lightning, 1900.*

State or Territory.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Annual.
Alabama		2	4	9	4	6		1		26
Arkansas			1	4	1	3	3			12
Colorado		1	1	5	2	7	1			17
Connecticut				4	3		1			8
Delaware					1	1				2
District of Columbia				1						1
Florida	1	1		4				2		8
Georgia		1	1	3	7	7				19
Illinois			12	4	9	13	4			42
Indiana			7	6	5	2	1			21
Indian Territory					1	1	1			3
Iowa		1	3	11	15	5	1	1		37
Kansas		2		2	8	2	2	1		17
Kentucky			4	6	2	8				20
Louisiana		1	1	4	1	3				10
Maine			1	3	3					7
Maryland			2	3	8	1				14
Massachusetts				1	4					5
Michigan			11	4	5	7				27
Minnesota		2	5	4	6	3	1			21
Mississippi		1	2	6	1					10
Missouri		1	3	7	5	3	1	2		22

Table I.—*Killed by lightning, 1900*—Continued.

State or Territory.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Annual.
Montana				2						2
Nebraska			9	8	3	4	1	4		29
New Hampshire				2						2
New Jersey			1	1	3	11				16
New Mexico				1	1	1	1			4
New York			1	9	13	14		1		38
North Carolina		2	2	4	8	8	1			25
North Dakota		1		4	2	2				9
Ohio			1	11	8	3				23
Oklahoma			1	1	2			1		5
Pennsylvania			7	5	27	19	1			59
Rhode Island				2		1				3
South Carolina		1	2	4	4	7				18
South Dakota		2	2	6	4	2	3			19
Tennessee		1	5		4	4	1			15
Texas	1	3	9	2	7	5	1			28
Utah						1				1
Vermont					2				1	3
Virginia		1	2	6	11	1	5			26
Washington							1			1
West Virginia			2	4		2				8
Wisconsin				5	10	8		4		27
Wyoming					2	1				3
Total	2	24	102	168	202	166	31	17	1	713
Cuba						2				
Porto Rico						1				

Table II.—*Injured by lightning, 1900.*

State or Territory.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Annual.
Alabama		1	3	3	3	6	1	2		19
Arkansas				3	1	1	2			7
California				3						3
Colorado				5		1				6
Connecticut			1	3		3	1			8
Delaware			1		8	4				13
District of Columbia				2						2
Florida				3	1	4	2			10
Georgia			2	3	4	8				17
Illinois		1	26	7	4	17	1	1		57
Indiana			5	24	15	6	4	1		55
Indian Territory						1				1
Iowa			3	9	21	6				39
Kansas		3		2			1			6
Kentucky			9	4	5	3				21
Louisiana				1		2	2			5
Maine					6					6
Maryland		1	2	7	8	8				26
Massachusetts			1	7	8	4			2	22
Michigan			12	19	11	14	1			57
Minnesota				2	3	11	2	2		20
Mississippi				2						2
Missouri		1	1	7	10	4	2	4		29
Montana				2						2
Nebraska			5	4	2	3	2	1		17
New Hampshire				4	2					6
New Jersey				3	11	20	29	1		64
New Mexico						1	1			2
New York		1	11	19	38	26	3	2		100
North Carolina			1	5	5	3				14
North Dakota			1			4				5
Ohio			2	16	33	22	3	1		77
Oklahoma			1				1	6		8
Pennsylvania			13	30	46	29	6	1		125
Rhode Island					5	4				9
South Carolina			1		1	10				12
South Dakota			1			2				3
Tennessee		2	4		1	3				10
Texas	1	2	4		3	9	8			27
Vermont				1		1				2
Virginia			1	2	5	4	4			16
West Virginia			4	3						7
Wisconsin		1	2	6	10	10	3	4		36
Total	1	18	117	221	270	244	79	26	2	973

TABLE III.—*Deaths by lightning, 1890–1900.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1890	......	......	2	6	8	37	55	12	......	......	......	......	[a] 120
1891	......	......	......	13	23	73	52	34	9	......	......	......	204
1892	......	......	......	5	27	74	67	54	15	6	1	2	251
1893	......	......	5	19	17	66	78	18	8	2	......	1	209
1894	......	2	6	14	45	96	60	78	29	6	......	......	336
1895	......	......	5	29	66	109	123	78	16	......	......	......	426
1896	......	1	6	26	71	45	89	75	21	6	1	......	341
1897	......	1	11	8	44	107	109	61	14	3	4	......	362
1898	......	......	1	2	44	71	110	86	41	12	......	......	367
1899	3	1	10	11	108	128	120	133	43	2	4	......	563
1900	......	......	2	24	102	168	202	166	31	17	1	......	713
Sums	3	5	48	157	555	974	1,060	795	227	54	11	3	3,772
Average	......	......	......	......	......	......	......	......	......	......	......	......	377

[a] Not used in computing the annual average.

TABLE IV.—*Number of deaths by lightning in the United States during the five years, 1896, 1897, 1898, 1899, and 1900; also the ratio of deaths in a million living, by rural population and total population and per unit area of 10,000 square miles.*

State and district.	Total population (1900).	Total number of fatal cases in 5 years, 1896–1900.	Rate per million.		Average number of deaths annually per unit area of 10,000 sq. m.
			Rural population.	Total population.	
New England:					
Maine	694,466	14	5	4	
New Hampshire	411,588	6	5	3	
Vermont	343,641	12	8	7	
Massachusetts	2,805,346	27	8	2	
Rhode Island	428,556	4	10	2	
Connecticut	908,420	16	8	4	
Average	....	13.2	7	4	2.3
Middle Atlantic States:					
New York	7,268,894	124	11	3	
New Jersey	1,883,669	37	10	4	
Pennsylvania	6,302,115	186	11	6	
Delaware	184,735	7	13	8	
Maryland	1,188,044	37	12	6	
Virginia	1,854,184	72	9	8	
Average	....	77.2	11	6	6.0
South Atlantic States:					
North Carolina	1,893,810	58	6	6	
South Carolina	1,340,316	76	12	11	
Georgia	2,216,331	62	6	6	
Florida	528,542	29	13	11	
Average	....	56.2	9	8	2.2
Gulf States:					
Alabama	1,828,697	68	8	7	
Mississippi	1,551,270	27	4	3	
Louisiana	1,381,625	81	6	4	
Texas	3,048,710	109	8	7	
Average	....	58.8	6	5	1.1
Central Mississippi Valley:					
Arkansas	1,311,564	49	8	7	
Oklahoma and Indian Territory	790,391	29	8	7	
Missouri	3,106,665	81	8	5	
Iowa	2,231,853	95	10	9	
Illinois	4,821,550	124	10	5	
Average	....	75.6	9	7	2.6

Table IV.—*Number of deaths by lightning in the United States during the five years, 1896, 1897, 1898, 1899, and 1900, etc.*—Continued.

State and district.	Total population (1900).	Total number of fatal cases in 5 years, 1896–1900.	Rate per million.		Average number of deaths annually per unit area of 10,000 sq. m.
			Rural population.	Total population.	
Upper Mississippi Valley:					
Minnesota	1,751,394	69	11	8	
Wisconsin	2,069,042	72	10	7	
Michigan	2,420,982	89	11	7	
Average		76.7	11	7	2.4
Upper Missouri Valley and Plains:					
North Dakota	319,146	32	21	20	
South Dakota	401,570	40	20	20	
Nebraska	1,066,300	70	16	13	
Kansas	1,470,495	52	8	7	
Average		48.5	16	15	1.3
Ohio Valley and Tennessee:					
Indiana	2,516,462	124	10	10	
Ohio	4,157,545	135	11	6	
Kentucky	2,147,174	71	8	7	
Tennessee	2,020,616	70	8	7	
West Virginia	958,800	28	6	6	
Average		85.6	9	7	4.7
Rocky Mountain and Plateau Region:					
Montana	243,329	22	25	18	
Wyoming	92,531	11	31	24	
Colorado	539,700	48	29	18	
New Mexico	195,310	8	8	8	
Arizona	122,931	8	13	13	
Utah	276,749	3	3	2	
Nevada	42,335	0	0	0	
Idaho	161,772	1	1	1	
Average		12.6	14	10	0.2
Pacific coast:					
California	1,485,053	2	0	0	
Oregon	413,536	1	1	0	
Washington	518,103	1	1	0	
Average		1.3	1	0	0.0

O

Plate I. AVERAGE ANNUAL NUMBER OF THUNDERSTORM DAYS IN THE UNITED STATES.

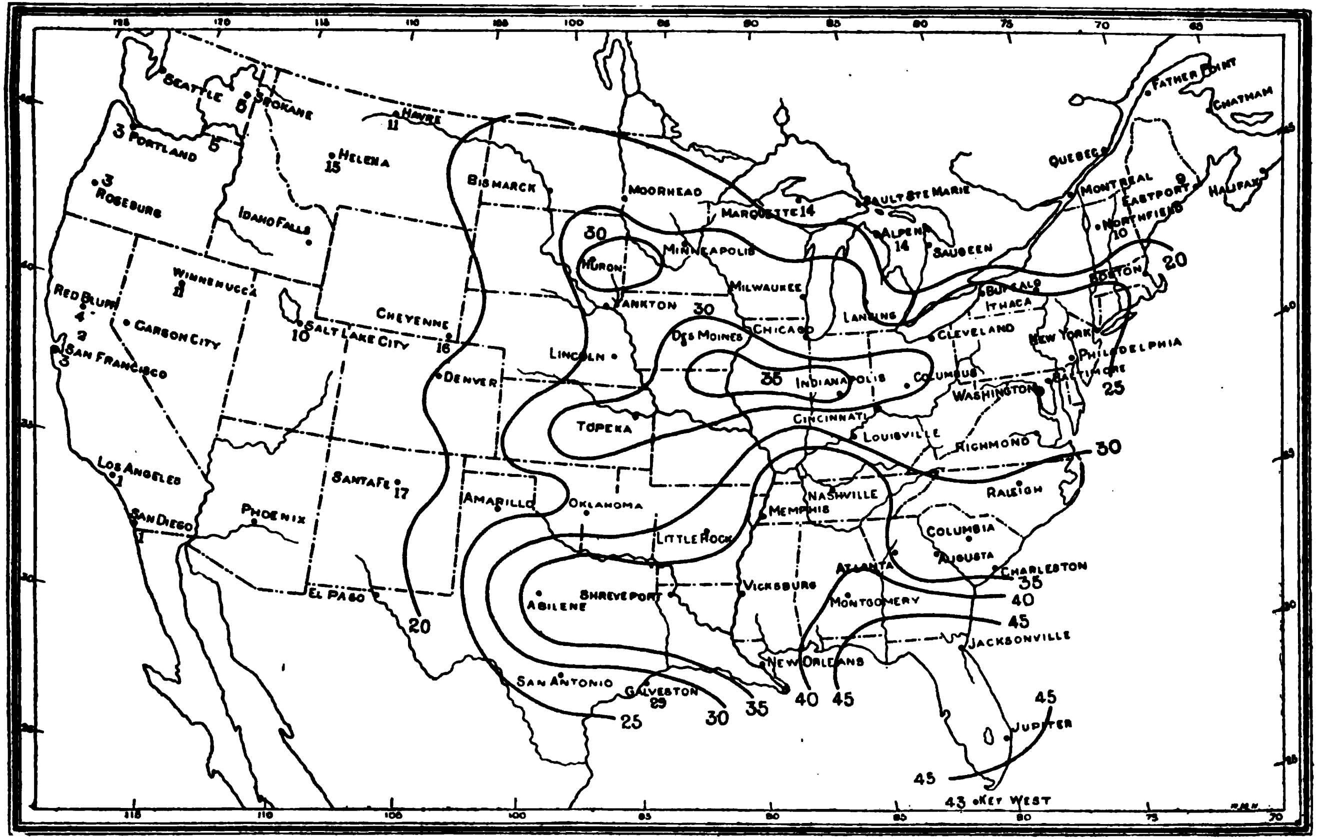


PLATE III.

Daily weather map July 8th, 1898, 8 p. m.

(Thunderstorms southwest of an area of low pressure)

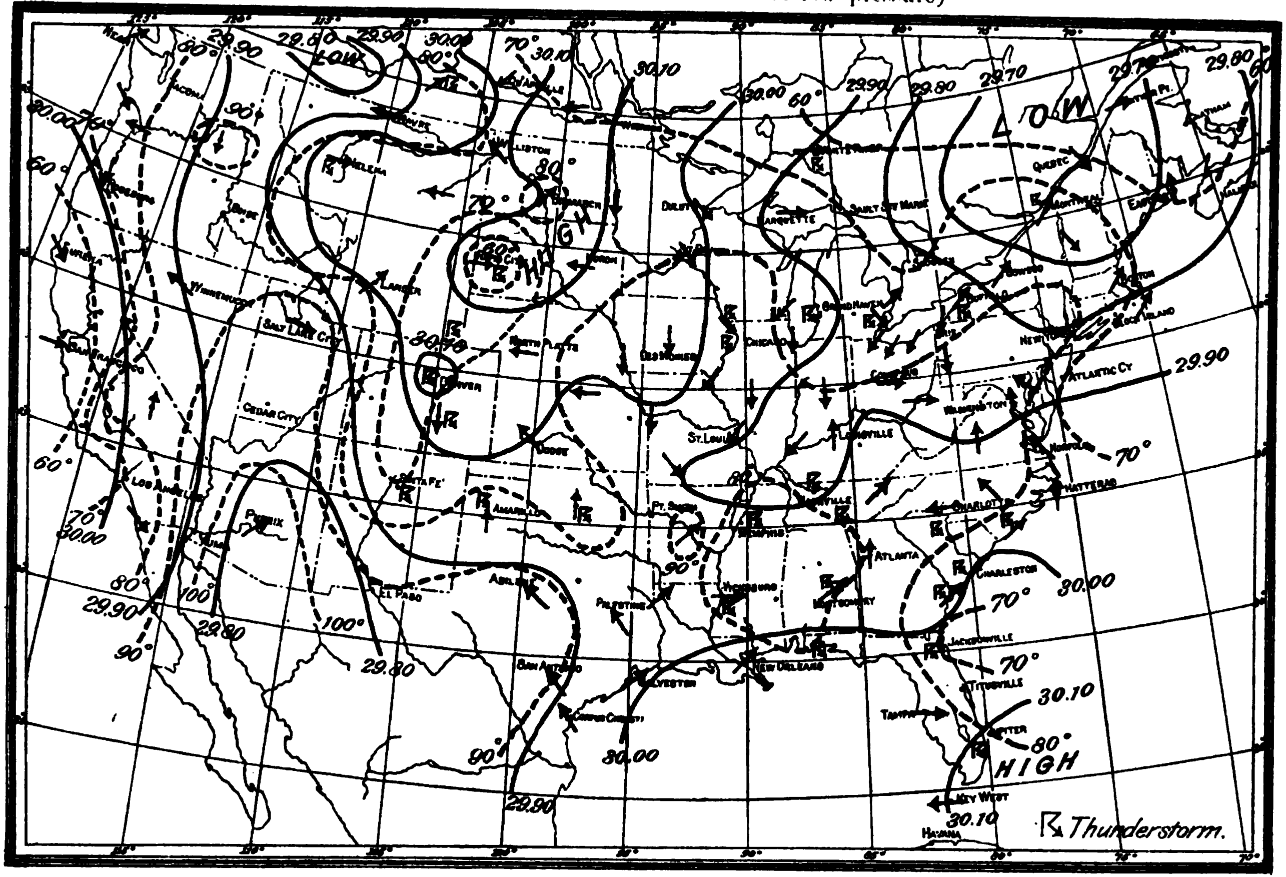
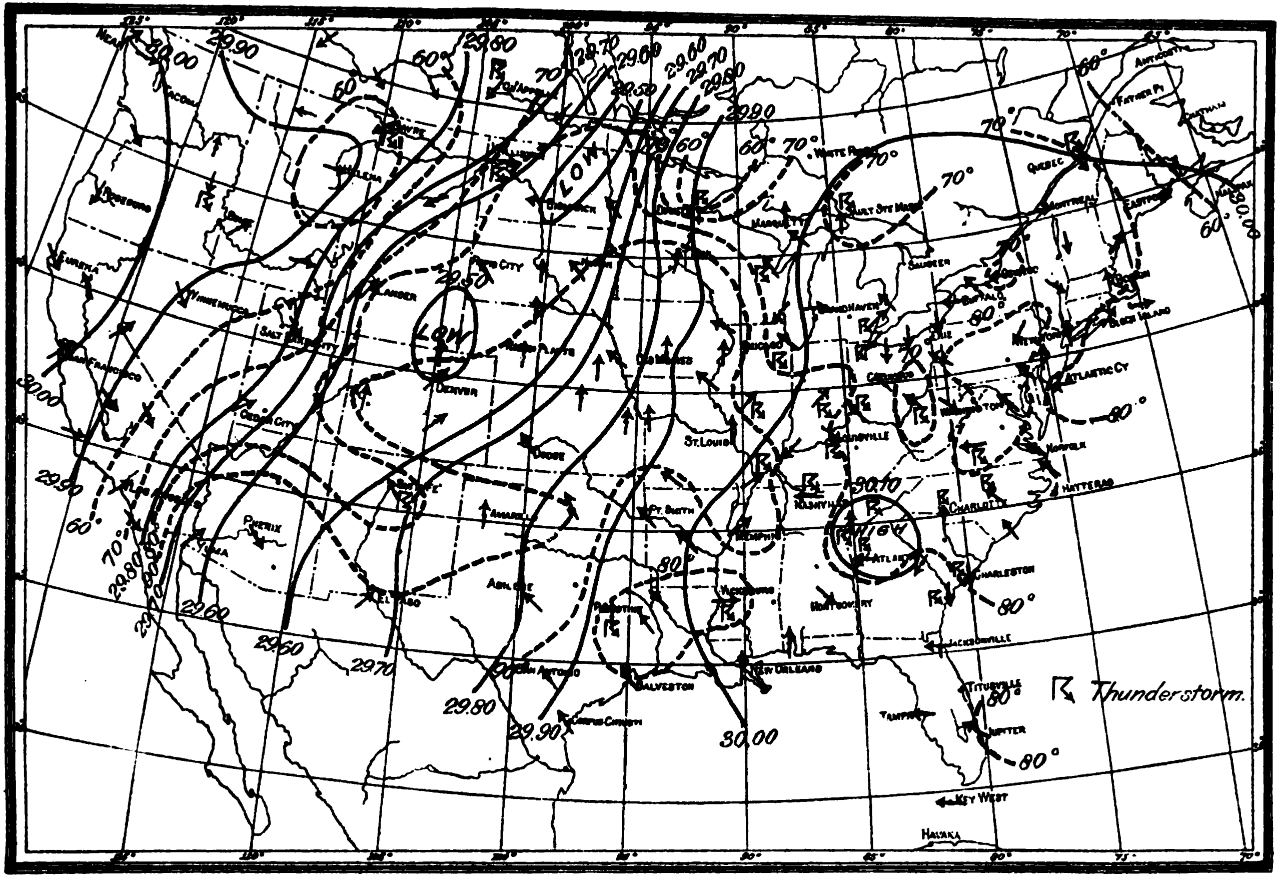


PLATE IV.

Daily weather map June 25th, 1901, 8 p. m.

(Thunderstorms in an area of high pressure)



BULLETIN No. 31. W. B. No. 265.

U. S. DEPARTMENT OF AGRICULTURE.
WEATHER BUREAU.

PROCEEDINGS OF THE SECOND CONVENTION OF WEATHER BUREAU OFFICIALS

HELD AT

MILWAUKEE, WIS., AUGUST 27, 28, 29, 1901.

Edited under the direction of WILLIS L. MOORE, Chief U. S. Weather Bureau,

BY

JAMES BERRY,
Secretary of the Convention,

AND

W. F. R. PHILLIPS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., March 19, 1902.

Hon. JAMES WILSON,
Secretary of Agriculture.

SIR: I have the honor to transmit herewith report of the second convention of Weather Bureau officials, held at Milwaukee, Wis., August 27, 28, and 29, 1901, recommending its publication as a bulletin of the Weather Bureau, the edition to be 5,000 copies.

This and the first convention (held at Omaha) have demonstrated their usefulness by affording exceptional opportunity for exchange of views and discussion of methods and means for advancing the work of the Weather Bureau.

This report contains many papers that will prove of interest and of practical value to the members of the Weather Bureau, as well as to its large corps of voluntary observers, forecast displaymen, and climate and crop correspondents. It also contains a number of papers that will prove of value to scientific meteorology.

Very respectfully,

WILLIS L. MOORE,
Chief United States Weather Bureau.

Approved:
JAMES WILSON,
Secretary of Agriculture.

PROCEEDINGS OF THE SECOND CONVENTION OF WEATHER BUREAU OFFICIALS.

MINUTES.

The second triennial convention of United States Weather Bureau officials at Milwaukee, Wis., August 27, 28, and 29, 1901, was the largest and most successful yet held. The attendance of 100 included the Secretary of Agriculture, the Chief of the Weather Bureau, members of his scientific staff, official forecasters, chiefs of divisions of the central office, and the officials in charge of the principal stations throughout the country.

The following members were in attendance:

Cleveland Abbe, Washington.
R. G. Allen, Ithaca.
A. McC. Ashley, Washington.
H. C. Bate, Nashville.
J. W. Bauer, Columbia, S. C.
W. S. Belden, Vicksburg.
James Berry, Washington.
F. H. Bigelow, Washington.
S. M. Blandford, Boise.
M. E. Blystone, Springfield, Ill.
W. T. Blythe, Indianapolis.
E. H. Bowie, Galveston.
H. B. Boyer, Savannah.
Al. Brand, Atlantic City.
F. H. Brandenburg, Denver.
B. H. Bronson, Bismarck.
E. B. Calvert, Washington.
F. P. Chaffee, Montgomery.
G. M. Chappel, Des Moines.
J. P. Church, Washington.
F. H. Clarke, Scranton.
F. M. Cleaver, Washington.
I. M. Cline, New Orleans.
Joseph L. Cline, Sandusky.
N. B. Conger, Detroit.
Patrick Connor, Kansas City.
H. J. Cox, Chicago.
W. S. Currier, Toledo.
D. Cuthbertson, Buffalo.
R. H. Dean, La Crosse.
L. A. Denson, Meridian.
W. M. Dudley, Mobile.
E. C. Easton, Baltimore.
E. H. Emery, New York.
S. C. Emery, Memphis.
E. A. Evans, Richmond.
W. H. Fallon, Grand Haven.
O. L. Fassig, Baltimore.
G. E. Franklin, Los Angeles.
W. M. Fulton, Knoxville.
E. B. Garriott, Washington.
E. J. Glass, Helena.
S. W. Glenn, Huron.
A. E. Hackett, Columbia, Mo.
R. M. Hardinge, Santa Fe.
R. B. Harkness, Houghton.
M. W. Hayes, Havana.
J. S. Hazen, Springfield, Mo.
A. J. Henry, Washington.
H. B. Hersey, Louisville.
R. J. Hyatt, St. Louis.
T. B. Jennings, Topeka.
L. N. Jesunofsky, Charleston.
E. P. Jones, Portland, Me.
James Kenealy, Cleveland.
C. E. Linney, Chicago.
G. A. Loveland, Lincoln.
P. F. Lyons, St. Paul.
J. B. Marbury, Atlanta.
C. F. Marvin, Washington.
A. G. McAdie, San Francisco.
E. W. McGann, New Brunswick.
A. J. Mitchell, Jacksonville.
Willis L. Moore, Washington.
S. L. Mosby, Ithaca.
L. H. Murdoch, Salt Lake City.
G. H. Noyes, Boston.
G. B. Oberholzer, Charlotte.
T. S. Outram, Minneapolis.
W. S. Palmer, Cheyenne.
H. R. Patrick, Marquette.
W. F. R. Phillips, Washington.
L. M. Pindell, Chattanooga.
U. G. Purssell, Sioux City.
George Reeder, Corpus Christi.
E. B. Richards, Little Rock.
H. W. Richardson, Duluth.
O. W. Roberts, Yankton.
J. H. Robinson, Washington.
G. N. Salisbury, Seattle.
C. F. Schneider, Lansing.
L. G. Schultz, Fort Worth.
J. M. Sherier, Davenport.
W. U. Simons, Key West.
A. F. Sims, Albany.
J. H. Smith, Carson City.
J. Warren Smith, Columbus.
P. H. Smyth, Cairo.
O. D. Stewart, Grand Junction.
C. M. Strong, Oklahoma.
L. M. Tarr, New Haven.
G. T. Todd, Dodge.
T. F. Townsend, Philadelphia.
C. F. von Herrmann, Raleigh.
B. L. Waldron, Columbus.
F. J. Walz, Chicago.
L. A. Welsh, Omaha.
H. E. Williams, Washington.
W. M. Wilson, Milwaukee.
A. B. Wollaber, Portland, Oreg.

The following guests and visitors were in attendance at one or more of its sessions: Mr. George McCurdy, Chicago, Ill.; Mr. Charles B. Murray, Cincinnati, Ohio; Mr. La Verne W. Noyes, Chicago, Ill.; Rev. Father F. L. Odenbach, Cleveland, Ohio; Mr. E. R. Sharwood, Philadelphia, Pa.; Mr. John Thorson, Milwaukee, Wis.; Rev. Judson Titsworth, Milwaukee, Wis.; Mr. Harvey M. Watts, Philadelphia, Pa.; Hon. James Wilson, Ames, Iowa; Mr. H. Helm Clayton, Bluehill, Mass.; Misses Mary and Julia Lapham, daughters of the late Dr. I. A. Lapham, Milwaukee, Wis.

FIRST SESSION.

Dr. W. M. Wilson, of the local United States Weather Bureau office, welcomed the convention as follows:

Mr. President and Gentlemen of this Convention: It is with unalloyed pleasure that I greet you this morning. I have looked forward to this occasion for several months, always with pride and pleasure, but not always without anxiety—with pride and pleasure in being the local representative of this magnificent body of my coworkers; with anxiety lest something be overlooked which might contribute to the success of this convention or to your personal pleasure and comfort while you are among us. There is one point, however, upon which I am sensitive. I have been telling the people of Milwaukee, during the past few months, so many wonderful things about you—for all of which I hope I am not to be held too strictly to account—that I am a trifle uneasy in my mind as to what my reputation will be after the convention closes. [Laughter.] I hope, however, that by stretching a point or two you may be able to measure up to all the promises I have made concerning you. I am not authorized to speak for the people of Milwaukee, but I feel competent to offer you a little advice, based upon my residence here during the last six or seven years. In the first place, you will please the people of Milwaukee if you make yourselves entirely at home. In the next place, if there is anything you want, and it is in sight, take it and use it, and ask to whom it belongs afterwards. If there is anything you want and it is not in sight, I would advise you to ring up Main 419, the office of the mayor of Milwaukee, the Hon David S. Rose. [Applause.]

Mayor Rose was formally introduced to the convention and addressed it as follows:

Gentlemen of the Convention: Dr. Wilson is a citizen of Milwaukee. We are perfectly familiar with his reputation, and were you as familiar with it as we are, you would not be surprised to know that he is liable to exaggerate sometimes. [Laughter.] I assure you that anything you may do will not create a false impression in the minds of the Milwaukee people. [Laughter.]

About fifteen years ago, when I became a citizen of Milwaukee, one of the first people to attract my attention was a slim-built, pale-faced, delicate, studious-looking young man, known to but a few of his closest neighbors and unknown to fame. Few who met him on the street with head down, apparently always in studious thought, would have even dreamed that in a few short years he would have attained to the proud distinction of being the Chief of the Government Weather Bureau. [Applause.] We have watched his course with pride, because we claim him as one of our own. But his career is not surprising to Milwaukee people, because Milwaukee is full of just such timber. [Applause.] To you who are strangers in the city perhaps it will be of interest to know in advance something of who we are and what we are. We welcome you with sincere pleasure; we welcome you as practical workers in a splendid cause. Your labor contributes to the building up of commerce and business, to the building up of cities, to aiding the people who are engaged in the practical pursuits of life. Milwaukee, with the best harbor on the great chain of lakes, with her splendid lake commerce and her wonderful freightage, watches the signals as they are displayed upon the local signal station and trusts them. The work so well begun by Mr. Moore long years ago gives us confidence in the Bureau, and the work so well begun by him has been carried on with fidelity and splendid ability by those who have succeeded him, especially by him who occupies the place of chief of our local office at the present time.

We have a population of upward of 300,000 thrifty, sturdy, progressive inhabitants. The city is a great manufacturing center. We produced last year upward of $175,000,000 worth of manufactured products. Our growth is of the sturdy kind, and rapid, too, because in the last census decade our percentage of growth was 39.54 per cent. We increased our population by upward of 85,000 inhabitants. Milwaukee undertakes to keep pace with her sister cities in the rapid march of progress. We appreciate the fact that it is the friction of individual competition that animates business, and that same spirit of competition that inspires individual effort is the strong lever that moves cities onward and upward. Our population is a cosmopolitan population—more cosmopolitan, perhaps, than that of any other large city of this Union, because we have represented here in our splendid citizenship every civilized nation on earth, all living together in perfect harmony, seeking to accomplish the greatest good for the greatest number. Our government is of the liberal kind, the kind that is exacted by a foreign-born citizenship; and while it is true that we act upon the principle of according the greatest liberty consistent with good order and good morals, it is likewise true that ours is the most orderly city upon this continent. Our percentage of crime is the lowest.

There is a popular fallacy in the minds of strangers who live remote from us that Milwaukee is given to the manufacture of but one special product. It is true that we do manufacture an exhilarating nectar, with which you have perhaps not yet become acquainted. You have now the opportunity. But while it is true that our brewing industry is a great one, it is likewise true that it pales into comparative insignificance when compared with other great manufacturing industries we possess, giving employment to upward of 85,000 operatives. I invite you, as you have the opportunity in the intermissions of business, to visit some of our public parks. Our park system is young in years, but old in beauty and attractiveness. We were confronted with the same question, the same important problem, as I esteem it, that comes to every city some time in the course of its existence, namely, whether it is better to establish one, or perhaps two, large parks or a number of small parks. Those who were clothed with the responsibility, in the exercise of what I esteem to be most excellent judgment, decided upon the latter plan. As a result, we have a large number of small parks distributed throughout our territory, thus affording to the poorer classes of our city opportunities enjoyed only by the rich in the large cities of the country. We have no tenement houses in Milwaukee; on the contrary, you find the humble cottage of the laboring man and the more pretentious residence of our artisans out in the free air of the suburbs. There they rear their children to strong and sturdy manhood. Our school system is a part of the old Badger State that places her in the foremost rank in educational matters. We appropriate upward of $750,000 annually for the maintenance of our public schools. We carry the elements of common-school education and lay them at the thresholds of all our people. Our splendid public library and museum building, recently erected at a cost to the city of $750,000, is one of the finest educational institutions in our State, beautiful in architecture, well equipped in every department. There you will find the children of our city, afternoon and evening, pursuing the studies and cultivating themselves for the splendid citizenship of which they are to become a part.

In behalf of all our people, I extend to you a most cordial greeting and a most hearty welcome. I trust that your labors here will be profitable to you, and that incidentally you will find opportunities for pleasure, so that when you return to your respective homes you will carry only happy memories of your visit to the Cream City. [Applause.]

Professor MOORE. Mr. Mayor of Milwaukee, I know something of the city of Milwaukee myself. I have lived here long enough to imbibe some broad principles of charity and good-fellowship that were instilled into me by association with its people. I remember a lawyer who at the time I lived here was not extensively known. He has since that time been twice elected mayor of this great city—twice received the suffrages of his fellow-citizens. It is a magnificent city and a magnificent people. [Applause.] Mr. Mayor, I shall not make any extended remarks, though I would like to talk to you as long as you have talked to us; but I know you have another engagement, and I will end by simply thanking you in behalf of this convention, and through you the people of the city, for the courtesies which they have extended to us.

President Willis L. Moore delivered his address (printed elsewhere in full) and formally declared the convention open.

Prof. Frank H. Bigelow read a paper on "Higher meteorology."

Mr. W. M. Fulton and Prof. Alex. G. McAdie read papers on "Supplying employees with apparatus for carrying on original scientific investigations under certain conditions."

Mr. L. G. Schultz read a paper on "Study of polarization of light with reference to weather conditions." Discussed by Professors Abbe and Moore.

Prof. Alex. G. McAdie read a paper on "Fog studies." Discussed by Professors Bigelow and Moore, Mr. Clayton, and Rev. Father Odenbach.

Mr. A. McC. Ashley, for Mr. D. J. Carroll, unavoidably absent, read "The personnel of the station force."

Mr. E. J. Glass read a paper on "Chinook winds." Discussed by Mr. H. Helm Clayton.

President Moore, in introducing Mr. Harvey M. Watts, of the Philadelphia Press, said:

> One of the most important parts of our work is getting information before the people in the press in a thoroughly intelligent way. Our difficulty in doing this is not the fault of the press, because the press is universally generous toward the weather service. They cooperate to the best of their ability in putting our information fairly before the people. They make it a leading feature of some of the most prominent parts of their publications. But there is a great ignorance of what should be general meteorological information. There are some few thoroughly scientific editorial writers who are giving thought to meteorological problems and who are really doing more to educate the people than the text-books, because they have such a tremendous constituency. One of these writers is Mr. Watts. He has done splendid work as a newspaper writer in furthering the cause of the science of meteorology and in striving for correct nomenclature in the discussion of meteorological problems.

Mr. Watts read a paper on "The forecaster and the newspaper."

Mr. M. W. Hayes read a paper on "Value of the climate and crop and storm warning services of the Weather Bureau to the industries of Cuba and other islands of the West Indies."

Mr. G. H. Noyes read a paper on "Value of the climate and crop and storm warning services of the Weather Bureau to the industries of Porto Rico." Discussed by Mr. J. L. Cline.

Dr. O. L. Fassig read a paper on "The westward movement of a daily barometric wave across the North American continent in July." Discussed by Professors Moore and Bigelow and Mr. Clayton.

Mr. H. Helm Clayton, for Mr. A. L. Rotch, read a paper on "A method for the systematic exploration of the atmosphere by means of kites."

The following papers were read by title: "A marked rise in the normal Baltimore temperature curve for May," by Dr. O. L. Fassig; "Advent of spring," by C. F. von Herrmann; "Lightning records and their utility in forecasting thunderstorms," by James Kenealy; "Career the Weather Bureau offers to young men," by Roscoe Nunn.

President Moore then acknowledged the presence of Misses Mary and Julia Lapham as guests of the convention, as follows:

> At the opening of this convention we paid our compliments to Dr. Increase A. Lapham. Surely the Weather Bureau recognizes the great debt of gratitude it owes to that great student and scientist, that patient worker in natural science, who gave so much to the world and for whom the world has done so little. The convention, through me, has extended an invitation to Misses Mary and Julia Lapham, daughters of Dr. Lapham, and now I extend to them the warm greetings of this convention. We are pleased that they have honored us with their attendance."

The convention adjourned at 1 p. m. to reconvene at 2.30 p. m.

SECOND SESSION.

The convention met at 2.43 p. m.

Dr. Phillips delivered his address as chairman of section 2.

Mr. G. N. Salisbury read a paper on "Systematic study of meteorology on stations."

Mr. F. P. Chaffee read a paper on "Meteorology in the public schools: How much should be attempted? Methods of teaching." Discussed by Messrs. Blandford, Oberholzer, Watts, Clark, and Jennings, Professor Abbe, Messrs. J. Warren Smith, Hackett, Connor, and the chairman.

Mr. G. A. Loveland read a paper on "Meteorology in colleges: To what extent is it taught at present? Should it be offered as an undergraduate or as a post-graduate course?" Discussed by Dr. Fassig and Professor Abbe.

Mr. J. Warren Smith read a paper on "Popular lectures on meteorology, including lectures to farmers' institutes, social gatherings, societies, etc.: Are such lectures valuable in proportion to time given? What should be the general character of such lectures?" Discussed by Messrs. McGann, Hazen, Professor Marvin, Messrs. Chaffee, Mitchell, Professor Moore, Dr. Cline, Dr. Fassig, Professor Abbe, Messrs. Richards and Berry.

Mr. C. E. Linney read a paper on "Climate and vegetation: Relation and influence of climatic elements and factors (temperature, rainfall, sunshine, etc.) to vegetable growth and development." Discussed by Mr. J. Warren Smith.

Dr. W. M. Wilson read a paper on "Climate and man; with special regard to climate and climatic elements as curative or causative agencies of disease, etc."

Dr. I. M. Cline submitted a brief "Synopsis of a course of lectures in medical climatology."

Mr. R. H. Dean read a paper on "Influence of climate on animal life."

The following paper was read by title: "Climate and thought," by Mr. E. C. Easton.

The convention adjourned at 5.55 p. m.

THIRD SESSION.

The convention met at 9.50 a. m., 28th.

Professor Garriott, as chairman of section 3, delivered his address.

Mr. F. J. Walz read a paper on "The relation between general and local forecasts." Discussed by Mr. E. H. Bowie.

In the temporary absence of Professor Cox, Mr. E. B. Calvert read a paper by the former on the questions, "Should the verifying change of temperature be smaller and should not the terms 'slightly warmer' or 'slightly cooler' be credited?" Discussed by Messrs. E. H. Emery, D. Cuthbertson, A. J. Mitchell, N. B. Conger, and Patrick Connor.

Professor Henry read a paper on the question, "Should not temperature forecasts be verified by the maximum and minimum readings?" Discussed by Professor McAdie and Mr. L. M. Pindell.

Mr. F. H. Brandenburg read a paper on "Facilities for systematic study of corresponding weather types." Discussed by Professor Moore.

Mr. F. P. Chaffee read a paper on "Importance of the synopsis preceding the forecast, and how to make the synopsis instructive to the public." Discussed by Mr. R. B. Harkness.

Upon motion of Professor Henry, Mr. Harvey M. Watts was granted permission to read a paper on "The Public *v.* The Forecaster." Favorably commented upon by Professors Moore and Abbe, and upon motion of the latter a vote of thanks was extended Mr. Watts.

Mr. J. H. Robinson read a paper on "The telegraph and weather service."

Mr. P. H. Smyth read a paper on "Importance of river-stage forecasts of the Mississippi and Ohio rivers and tributaries in periods of low water." Discussed by Mr. L. M. Pindell.

Mr. H. B. Boyer read a paper on "Weather forecasts and the public."

The following papers were read by title: "Value of the dew-point in forecasting weather under certain conditions," by Peter Wood; "The double observation as a means of improving forecasts," by Lee A. Denson; "Substitution of acetylene gas for oil in storm-warning lanterns," by H. W. Richardson; "Verification of forecasts," by J. B. Marbury; "Forecasting for rivers of small drainage area," by Charles F. von Herrmann; "Should temperature forecasts be verified by maximum and minimum readings?" by P. F. Lyons.

The reading of the preceding papers by title concluded, at 12 m., section 3 of the programme, and without adjournment the convention proceeded with section 4.

SECTION 4.

Prof. A. J. Henry, chairman of section 4, delivered his address.

Mr. E. A. Evans read a paper on "Meteorological and other forms and reports: Should they be simplified; are other modifications desirable?" Discussed by Mr. E. C. Easton.

Mr. J. W. Bauer read a paper on "The examination of monthly meteorological reports of voluntary observers: Is it desirable to report back to the voluntary observer the errors and irregularities discovered in his report?"

Mr. S. C. Emery read a paper on "The best means of preserving records for reference and study." Discussed by Professor Henry.

The following papers were read by title: "Necessity for binding and otherwise preserving the publications of climate and crop sections," by W. S. Belden; "Use of collected data," by W. S. Palmer; "Records in court," by C. E. Linney.

At 1 p. m. the convention adjourned to meet at 2 p. m.

FOURTH SESSION.

SECTION 5.

The fourth session was called to order at 2.15 p. m. Address by chairman, Mr. James Berry.

The first paper read was, "Should the monthly report of the climate and crop sections contain only original matter?" by Mr. G. A. Loveland.

Mr. T. B. Jennings read for Mr. S. W. Glenn, who was indisposed, a paper on "Should the remarks of climate and crop correspondents be published in the weekly bulletins?" Discussed by Mr. C. F. von Herrmann.

Mr. M. E. Blystone read a paper on "Is it advisable to distribute the night forecasts by the rural free delivery?" Discussed by Mr. C. F. Schneider.

Mr. S. L. Mosby read for Mr. R. G. Allen, who was indisposed, a paper on "How many climate and crop correspondents are required to meet fully the needs of the Bureau in its climate and crop service?" Discussed by Mr. A. E. Hackett, Mr. James Berry, and Mr. J. P. Church.

Mr. J. Warren Smith read a paper on "Phenological data."

Mr. C. F. von Herrmann read a paper on "Climatological studies, with reference to the crops of the several sections."

Dr. O. L. Fassig read a paper on "Maryland climatological studies." Discussed by Mr. F. J. Walz.

Mr. W. T. Blythe read a paper on "Methods of saving time in the distribution of forecasts." Discussed by Mr. C. E. Linney.

"Forecast cards on street cars" was the subject of a paper by Mr. N. B. Conger. Discussed by Messrs. L. M. Pindell and J. B. Marbury.

A paper on "Weather symbols on rural free delivery wagons" was read by Mr. L. M. Pindell.

Dr. Phillips moved that, as it was understood that several members had prepared papers which could not be entered on the programme, such members be permitted, under the circumstances, to deposit their papers with the secretary, and that these papers be regarded as read by title.

Adopted.

Notice was given that Mr. John Thorsen had courteously granted permission to all members of the convention and the ladies accompanying them to visit the art gallery at any time without charge.

A paper on "Climatology of Florida with regard to crops," by A. J. Mitchell, was read by title.

The fifth section was concluded at 4.55 p. m., and the convention immediately proceeded with section 6 of the programme.

SECTION 6.

Address by Prof. Charles F. Marvin, chairman.

Dr. O. L. Fassig read a paper descriptive of a "Device for automatically recording beginning and ending of light precipitation." Discussed by Prof. C. F. Marvin and G. R. Oberholzer.

Mr. T. S. Outram read a paper on the question, "Is exposure at Weather Bureau stations for all instruments satisfactory?"

Mr. A. F. Sims read a paper on "Suburban observatories."

Mr. G. R. Oberholzer read a paper on the following subject: "The maximum and minimum thermometers are too fragile; can not effective protection be devised without impairing sensitiveness; should not aluminum scales be discarded?" Discussed by Mr. P. F. Lyons and Prof. C. F. Marvin.

Mr. A. B. Wollaber read a paper on the question, "Should not thermographs be furnished to voluntary observers, the records to be kept at section centers?"

Mr. W. M. Fulton read a paper on "The introduction of automatically recording river gages."

A paper on the subject of "River gages in the Upper Mississippi Valley," by Mr. W. W. Carlisle, was read by title. This concluded section 6 of the programme, the convention adjourning at 6.15 p. m. to meet at 10 a. m., August 29.

At 8 p. m., in the convention hall, 30 selected lantern slides, giving fog views made at the United States Weather Bureau Observatory at Mount Tamalpais, Cal., were shown on screen by Mr. McAdie. These views were commented upon by Professors Abbe and Marvin, Dr. Fassig, and others.

FIFTH SESSION.

At this, the final session, presided over by Professor Moore, addresses (printed elsewhere in proceedings) were delivered by Messrs. B. W. Snow, of the Orange Judd Farmer; Charles B. Murray, editor of the Cincinnati Price Current; La Verne W. Noyes, Chicago; E. R. Sharwood, Philadelphia; Rev. Father Odenbach, St. Ignatius College, Cleveland; Messrs. A. W. Machen, superintendent free delivery service, Post-Office Department; H. M. Watts, Philadelphia Press, and Hon. James Wilson, Secretary of Agriculture.

Mr. Calvert introduced the following resolution, which was adopted:

Whereas the officials of the United States Weather Bureau, in convention assembled, this 29th day of August, 1901, are most highly appreciative of the uniform courtesy, cordiality, and liberality with which we have been received and entertained during our sojourn in the Cream City: Therefore, be it

Resolved, That the hearty and sincere thanks of this convention be extended to the citizens, to the press club, and to the press of the city of Milwaukee, to the officials of the Chicago and Northwestern Railroad, and to Dr. Wilford M. Wilson, our able representative, for the many courtesies that they have all so kindly extended to us, and for their indefatigable and successful efforts in arranging for our entertainment and comfort; and be it further

Resolved, That the secretary of this convention be instructed to send a copy of these resolutions to Mr. E. C. Wall, chairman of the citizens committee; to Mr. William A. Bowdish, president of the press club; to Mr. H. R. McCullough, third vice-president of the Chicago and Northwestern Railroad, and to Dr. Wilford M. Wilson, section director of the United States Weather Bureau.

Professor ABBE. Moved, that the convention requests the secretary of the meeting to address a letter to Mr. John W. Smith, of Boston, expressing sympathy with Mr. Smith in his bereavement and regret at his absence, occasioned by the death of his mother.

So ordered.

Mr. H. E. Williams, chief clerk of the Weather Bureau, in rising to move a resolution, spoke of the pleasure it had given him to meet, face to face, so many members of the Weather Bureau whom he had never seen before, as well as those with whom he was acquainted. For many years he had been in correspondence with them in connection with the business of the central office, and had learned to respect, admire, and love the spirit that animated them, the thorough devotion to duty, and the earnestness of purpose that they manifested, and which he had found to prevail throughout the membership of the Bureau. One of the most beneficial effects of these conventions, he thought, was the spirit of solidarity, comradeship, and mutual esteem that inevitably resulted from them. Mr. Williams then moved a vote of thanks to the proprietors of the Hotel Pfister for their more than common courtesy in affording unusual facilities to the convention, as well for the uniform politeness and attention of the employees of the house. This was unanimously adopted.

After brief remarks by Mr. Alexander G. McAdie, Mr. A. J. Mitchell, Professors Bigelow and Moore, the latter at 1 p. m. declared the convention adjourned sine die.

A banquet was given the members of the convention at the Hotel Pfister by the citizens of Milwaukee on the evening of the 29th.

Through the efforts of Dr. W. M. Wilson, the local Weather Bureau official, generously seconded by the citizens of Milwaukee, the arrangements for the convention were most complete, nothing having been left undone that would have contributed to its success. The sessions were held in the banquet hall of the Hotel Pfister, at which all the members of the convention were quartered. This proved of very material advantage in view of the length of the programme and limited time at the disposal of the convention, the business of which was completed in a very satisfactory manner within the three days allotted.

Through the very efficient services rendered by Mr. R. M. Reese, stenographer to the honorable Secretary of Agriculture, the proceedings of the convention were very fully and accurately reported.

GENERAL SECTION.

PRESIDENT'S ADDRESS.

Prof. WILLIS L. MOORE, *Washington, D. C.*

GENTLEMEN OF THE CONVENTION: It is not necessary for me to extend any welcome to you after the remarks of Dr. Wilson and the eloquent speech of the mayor of Milwaukee, but in opening this convention, which is the most auspicious of any we have held, it may be appropriate to give a few, brief reminiscences. I am down on the programme to deliver an address. I shall not do so. I wish simply to talk to you for a few moments, and then we shall proceed with the regular order of the program.

It is interesting to recall that in 1870 this weather service had its inception. It is also interesting to note that the appropriation at that time was $20,000, and that to-day the people of the United States spend nearly one million two hundred thousand dollars annually for this service, and are satisfied with the expenditure; for the service has not been compelled to petition anybody for its maintenance for many years. Congress has freely given us every dollar we have estimated for in the past four years. Away back in 1870, and prior to that time, there were a few indefatigable workers whose object was the creation of an institution that was finally to send to Milwaukee such a convention as this. Dr. Lapham, whom everyone in Milwaukee loved, was one of those earnest workers, gentle in his way and modest in his demeanor. He and our own Professor Abbe [applause], did more than any other two persons to create the present weather service. Redfield, Espey, Loomis, Maury, Coffin, and other scientists had demonstrated the theory of storms as we understand it to-day. Neither Lapham nor Abbe added materially to that theory, but Abbe collected observations of the weather in 1869, with the aid of the Cincinnati Chamber of Commerce and the Western Union Telegraph Company, and began making forecasts for the purpose of giving an example of what could be done. Lapham collected records of some 2,000 disasters on Lake Michigan, the majority of which would have been averted had there been a weather service. Lapham went to the National Board of Trade and there got resolutions. He made such a lucid argument with the facts that he presented that finally a Congressman from Wisconsin, Gen. Halbert E. Paine, introduced in the Congress a resolution appropriating the $20,000, to which I have just referred.

From that modest beginning has grown the weather service of to-day. It embraces an area from the north coast of South America to the remotest confines of Canadian habitation, and from the Atlantic to the Pacific. It is the greatest survey of atmospheric conditions ever presented to the eye of the forecaster, and if meteorology, in its weather predictions, comes to be an exact science it will be due to the energy and liberality of the United States Government in presenting such a magnificent daily picture for the study of the meteorologist. If it ever comes to the time when we can forecast the character of the coming seasons, so that the farmer may conserve his energies and spend them to the most profitable advantage, it will be due to the scientific study of such a broad atmospheric picture as the United States daily presents. It will not be due to chance.

When we began the weather service there was but little attention paid to us, except by the funny paragrapher. We were abused and ridiculed sometimes; more often treated with good-natured jest. The old mariner laughed at us; he sailed in the face of the storm signals, and delighted to do it. It was a long time before we convinced him of our value; and in fact we did make a great may mistakes in those days, and it was a long time before we were entitled to the confidence of the marine interests. But to-day hardly a ship sails, the master of which does not take cognizance of the weather map, daily forecasts, and storm signals. Down in New Orleans, when the recent storm came in from the Gulf, our official issued warnings that the papers of New Orleans say reduced the wreckage on the open waters at least $1,000,000. He was able to say to Galveston what was just as valuable to it as the storm warning was to New Orleans, viz: "You need have no fear; this storm will go northward and not strike the Texas coast. Only don't let your vessels sail out into it." That reassured the Galveston people and prevented their being panic-stricken.

I wish now briefly to refer to some important innovations that have taken place as a result of our convention at Omaha. New instrumental equipments have been placed at nearly all weather stations, so that nearly every observatory to-day is equipped with standard self-recording apparatus, whereas before but few even of our first-class stations had such adequate apparatus. We have erected at more than one-half the marine ports tall steel towers for the display of marine warnings, where before the warnings were displayed from anything to which a lantern could be tied. We have experimented to determine the most powerful lantern we could make that would be suitable for our use. We have inaugurated in the lake region what we call the lake marine service, with headquarters at Detroit, and we have made a study of the fog areas, so that at different seasons of the year the mariner may know on what portions of the different lakes he will meet the greatest percentage of fogginess. It was simply the establishment of the normal, that is all; but, by collecting the records from many vessels, we are able to say where, during certain seasons, there will probably be encountered the greatest amount of fog. The extension of the forecast system has been important. By cooperation with Mexico we now exchange observations with that country. By an extension of the service as an incident of the war with Spain we now have a service that covers the West Indies and surrounds the Gulf of Mexico. By a recent arrangement with the English meteorological office we get daily observations from the west coast of Europe. By the completion of the German cable from Lisbon across to the Azores and thence to New York we get observations from the Azores which are highly valuable in making warnings for the guidance of transoceanic steamers. The extension of the marine part of our work has resulted in enabling our forecasters to make fairly accurate ocean forecasts for outgoing steamers. We have to interpolate a little for the pressure of the North Atlantic, but it is found that our estimate is highly valuable to commerce and is accurately made. Most of the things that I have referred to are important innovations that the marine interests have been seeking for years, and we are glad they have been obtained. Many other things that were discussed at our Omaha convention, as you know, have been incorporated in the weather service. I think the most profitable instruction I have ever received as chief of this service came from listening to your discussions at that convention three years ago. This is a coming together of supervising officials. One rubs up against another, gathers his ideas, takes them home, and applies them to his own work. It is a sort of clearing house for weather ideas.

One of the last and most important innovations in the weather service has been accomplished through the cooperation of Mr. Machen, Superintendent of the Rural Free-Delivery Service. We have had the hearty cooperation of the Post-Office Department, and to-day the mail carriers going out into the rural districts carry with them little slips containing the daily forecasts, and Mr. Machen finds it one of the most popular features of the rural free delivery. This part of our work will be greatly extended in the future.

There is another innovation that I hope to have made. I have not yet presented it to the Secretary of Agriculture, but I believe he will give it his approval, as he has always shown a disposition to favor anything that means help to the Weather Bureau. That is the construction of individual observatories in every city where we have a station. So far Congress has freely given us money to build separate meteorological observatories at isolated places on our various coasts. We are constructing six this year. I propose to place the matter before Secretary Wilson, so that he may place it before Congress, with a view to completing a few buildings each year, so that in a city like Milwaukee there would be erected a Weather Bureau building that would be in fact a Weather Bureau observatory. I believe that Congress will approve this.

One word about the discipline of the service and I am through. I think this convention, as I look over the faces of those present, speaks for itself of the merit system. It is the intention of the central office that only men of tried capacity, men who possess both ability and good character, shall be selected for the responsible positions of the weather service. Secretary Wilson has exacted of me only one condition in the making of recommendations to him for preferment in the service, and that is that my recommendations shall be fairly made. It has been my honest endeavor to place before him only the names of the men who were best fitted and most entitled to advancement when promotions were to be made. I have tried to discharge this duty righteously. I may have made errors. I may not, at times, have satisfied some, but I believe that I have satisfied the majority, for I can truthfully say that there has never been a preferment in the weather service since I have been Chief of the Bureau in which any consideration entered except the welfare of the public service and the merit of the official. As an instance, I may cite the fact that last winter Congress created an additional professor and three additional national forecasters. Now, that act became law the latter part of January or the first of February. I did not make the nominations to the Secretary until the 1st of June, and during that interval there was not a letter or personal application received from any person asking for any of these places. There was no intercession on the part of outside influences in behalf of any man in the service, and I think that fact is the strongest evidence that our people are willing to rest their cases with the central office and allow it to select the men for important commissions unhampered by selfish intercessions. [Applause.]

HIGHER METEOROLOGY IN THE UNITED STATES WEATHER BUREAU.

By Prof. FRANK H. BIGELOW, *Washington, D. C.*

Such phrases as the "higher meteorology" are of very doubtful value, for they are, in fact, taken out of a cheap vocabulary which passes current for a time among people, while their view of things is limited to a small horizon. A thousand-dollar note is not higher money than a dollar; they should be equally good currency. A true fact is sound knowledge, be it concerned with large or with little things. The orbit of a subatomic ion is as important as the path of a distant star with a parallax of a fraction of a second of arc, though the former we may hold in the hollow of the hand, and the light from the latter, starting before we were born, may not reach us till we have gone on our own long journey. A man may work a lifetime to secure such a fact as that, but he lays his tribute upon the entire universe in doing it, and he inscribes the mark of immortality upon his name. Nature deals with facts, honest work, and inspiration. She rewards man with the happiness which comes to his mind through the consciousness of effort, possibly with success, and the chance to multiply his single talent a thousandfold in the service of mankind. However, in a practical way, science seems to develop in three threads of effort—statistical, economical, and theoretical—and in a completed science they are mutually interwoven to support one another. Astronomy has its star catalogues, its Nautical Almanac, and its Theoria Motus; these are its facts, its theory, and its forecast. Electricity and magnetism has its physical measures in the laboratories made by nature and by man, its magnificent mathematical analysis, and its telegraphy from city to city, from land to land, and between the sun and the earth; also its dynamos and its physical chemistry.

Meteorology has its climatological statistics, its synchronous charts and forecasts; and alas, would that we could also add its theory in satisfactory form. Furthermore, these three-stranded ropes of astronomy, of electricity and magnetism, and meteorology, are in nature but parts of the great cable that binds together the sun and the earth, which may be called the solar-terrestrial physics. We are but just entering upon an adequate conception of this truth in recent years, and are slowly and even painfully unraveling the threads of this grandest of all problems, so enormous in extent as to task severely the powers of the strongest minds to master even the general relations of its parts, and so difficult in its details as to baffle our keenest analysis and imagination. It is my purpose to-day to speak of this great subject as I see it, hoping to convey at least some proper idea to you of the splendid field of thought that it has been my privilege to work in, since my first attachment to the Cordoba Observatory under the Southern Cross. Is it not, by the way, a singular fact that the three Americans who have so far made a serious effort to solve the dynamical problems of meteorology, Professors Ferrell, Abbe, and Bigelow, each began their studies as astronomers and passed over into meteorology in their riper years. We have respectively served in observatories, in the Nautical Almanac Office, and in the Government service for meteorology. We became acquainted practically with numerous observations, long and tedious computations, and developed a sort of imagination capable of conceiving problems on a grand scale, and a patience of study and research before which difficulties tend to yield. This experience may be significant or not; but it is my impression that the meteorologists of the future will be recruited from among the astronomers rather than from the physicists of the laboratory. In a word, the highest problems of meteorology are in effect astronomical, since they are concerned with the equations of motion. Meteorology is, however, even more difficult than astronomy, because it must employ the hydrodynamic equations instead of the dynamic, and they are necessarily much more complex. But astronomy is fast becoming astrophysics, and there the two branches of this great science flow together and become mutually related. The question has no doubt presented itself to your minds, Why is it, if the observations, the theory, and the forecasts are so intimately connected in meteorology, that the theory has had so little influence upon the practical forecasts of the Weather Bureau? The answer is probably twofold: First, that the theory has been very imperfect and incorrect; and second, that the officials have not generally qualified themselves as students to use scientific results involving mathematical and physical analysis. As to the first: Scientific progress depends upon three distinct steps, (1) the collection of observations; (2) the development of pure theory as a mathematical analysis, and (3) the comparison of the possible solutions in mathematics with the results of observations.

You may have noted that this procedure has been followed in the three investigations which I have carried out since my connection with the Bureau, viz, the relations between solar and terrestrial magnetism and meteorology, the international cloud observations, and the barometry of the United States, Canada, and the West Indies. In each case the whole mass of observations was compiled ready for analytic treatment. At the same time all the mathematical discussions heretofore available have been studied, classified, and clarified ready for application to the reduced data. The third step of welding the observations and the theory together is only partially completed up to this time. The immediate consequence of this method is to severely test and criticise the existing speculative meteorology current in our books and in the popular understanding. It is necessary to say that I have been surprised and disappointed at the weakness and inability of many well-known views to bear this strain. To illustrate very briefly: In barometry we have had five methods of reduction to sea level, by Guyot's Tables, the Monthly Constants, the Ferrel Tables, the Hazen Tables, the Morrill Tables. My conclusion is that Ferrel's point of view and method of reduction is admirable, and that the Hazen system ought not to have superseded it. Hazen's method takes no true account of the plateau effect, of the vertical temperature gradients, of the difference between the current and the normal pressure. His argument from Mount Washington as an analogue to the Rocky Mountain Plateau is not sound. But I must say that his device of reducing the station pressure as if the sea-level pressure were 30 inches works in the same direction as Ferrel's correction, so that his practical results for forecasting are approximately correct, except in the cases of cold waves on the northern plateau and the hot waves on the southern plateau. I understand that the real reason why Ferrel's method was abandoned is that the Signal Service could not sufficiently understand it. Yet in effect it is a method simple in principle and easy of application, as you will no doubt admit when the subject is brought to you in a different form. We have recently improved the Ferrel method and extended it to the sea level, the 3,500-foot plane, and the 10,000-foot plane, so that daily maps can be constructed upon one as quickly as upon the other of them. The forthcoming report on barometry contains normals of pressure, temperature, and vapor tension at the station and on these three planes. It is my belief that theory and practice in barometry will support each other satisfactorily in the future.

Regarding the theory of local cyclones and the general cyclone of the hemisphere, it can only be stated here, in my brief paper, that the Ferrel local cyclone does not exist in nature, because there are no boundaries about it, as is assumed in the analogue of a cylindrical vessel holding a mass of circulating water. The German local cyclone is likewise an ideal one, because there is no powerful central vertical current such as that theory requires. The Ferrel canal theory of the general circulation is only true in part, because the interchanging motion is not wholly from the Tropics northward in the upper strata to the poles and thence southward in the lower strata. The great currents, on the other hand, move northward and southward on the same levels most rapidly in the stratocumulus level, and in trying to pass by each other they generate our cyclones and anti-cyclones, which are practically confined to the strata within 2 miles of the ground. Criticism has done its work, and rejected an entire literature of meteorology. The constructive process must now be continued. The problem is quite clear to my mind, but the analytic difficulties are very great, and I may not succeed in resolving them myself. I shall be quite content to have placed the right point of view before some abler student of hydrodynamic forces and motions. The original trouble came from speculating in the mathematics without a knowledge of the facts themselves to be accounted for. If the results of the International Cloud Observation of 1896–97 had been in hand, much that we now call meteorology would not have been written. The official reports of the seventies show that Professor Abbe was urging nephoscope and altitude observations in those days. It is a pity that his advice was not followed. Consider the time and labor wasted and money uselessly expended in trying to construct a theory of meterology from guessing as to the motions of the upper atmosphere. A few thousand dollars spent then would have been the best of investments. It is now a thankless task to try to reverse a theory of science that has gone forth; it is better to build upon than to destroy the work of our predecessors.

The problem of solar and terrestrial magnetism still remains in the crucible of scientific criticism, owing to the difficulty of handling the observations and accounting for the results. My own investigation constitutes the most comprehensive and thoroughgoing of any yet undertaken. The method of treating the observations by deflecting vectors is universally accepted and will take its place permanently in science. So far as others have carried their computations, our results are in harmony, but no one has yet covered the field fully enough to be better competent to draw more correct conclusions. Pupin's and Ebert's experiments, together with the theory of ionization, interpret the corona as an electric radiation controlled by a magnetic field; Van Bemmelen finds a distribution of the polar field at the earth like mine; Schuster's distribution of disturbing vertical vectors is the same as mine; the theory of ionization seems to account remarkably for several gaps in the theory which I adopted to account for my results. I am convinced that I shall have less to modify than others who wrote upon the subject several years ago. Ionization has already sent a thrill of delight throughout the scientific world. An attempt has been made to review and correlate the present aspect of the entire problem in my report on the total eclipse of May 28, 1900, and I am glad to see that the Weather Review is beginning to take cognizance of this splendid subject by quoting Wilson's paper in a recent number.

It is not too much to say that meteorology is turning over a new leaf in these days. Speculative theories are being discarded, and we must build anew upon the motions of the air as disclosed by cloud observations, and upon the gradients of pressure, temperature, and vapor tension as measured in kite and balloon ascensions or by cloud computations. The new machinery of mathematics and the computing tables have been reconstructed as satisfactorily, normals have been worked out on three reference planes, and ionization has been admitted to explain the atmospheric electricity and magnetism, also the residual effects of radiation. Work opens up to us for the immediate future more exacting and more promising than anything we have known in the past, and it calls for better scholarship, more men, and more money. Our experience shows how unwise it has been to hope to solve the practical problems of forecasting without any more data than we could pick up from the ground. You know as well as I do how much progress has been made toward any important improvement in the forecast during the past twenty years. At the same time the commercial demand for better forecast work is pressing us very hard, and our mistakes are more deeply regretted than they were years ago.

There is a curious alignment of meteorologists going on in the world, brought about by natural causes. While the opportunity and the demand for practical meteorology has put America at the front in this respect, we must admit that the Europeans are doing better in theoretical and in exploring work. They have many more scholars in mathematics and physics than we have, and while kite work has been pursued about alike in both countries, the balloon observations, upon which results in the higher strata depend, are being made entirely on the other side of the water. It seems to me that we ought to even things up a little at this place. The labor of research is much too great for the few of us now assigned to it in the central office. I believe I am correct in saying that the Chief of the Weather Bureau and the corps of scientists are unanimously in favor of expanding our research work by adding to our present organization a new division for that purpose. Such investigation must go on continuously, not tentatively in small pieces as emergency arises. The path before us is perfectly clear, and it is only a question of labor to solve our problem. I do not, for one, think we are longer justified in continuing to conjecture regarding the elementary facts concerned with the dynamics of storms.

THE ADVISABILITY OF SUPPLYING EMPLOYEES WITH APPARATUS FOR CARRYING ON ORIGINAL SCIENTIFIC INVESTIGATION UNDER CERTAIN CONDITIONS.

By Mr. WESTON M. FULTON, *Knoxville, Tenn.*

In his work entitled The Aims and Methods of Meteorological Work, Prof. Cleveland Abbe says:

> The proper aim of a weather bureau must be to do its part in the development of all four aspects of scientific activity—observation, induction, deduction, and

application. Efforts have sometimes been made to show that a popular government is, and should be, a purely utilitarian and popular institution and that its duty is to develop the art of applying the sciences, not that of constructing them. But every art is imperfect in its beginnings. If a weather bureau is to apply meteorological science for the benefit of the community it must be careful to see to it that this art of prediction progresses equally with the general progress of science, just as is the case in astronomy, chemistry, and the exact sciences. Moreover, it must stimulate the growth of the highest phases of meteorological science. It must stimulate investigation in order that it may have a solid foundation whereon to build improvements in forecasting.

There must therefore be a certain proper proportion in the work of every weather-bureau station between the attention given, on the one hand, to observations and predictions and, on the other hand, to investigation. It is only by the increase of knowledge in both these fields that the practical utility of a weather bureau can continue to respond to the increasing demands of the people who support it.

The experimental side of meteorology is usually less prominent than its observational side; nevertheless, there are many questions involved in this science that must be settled by experiment and measurement in physical laboratories, as distinguished from the observations made at meteorological stations.

It is believed that all must concur with Professor Abbe in the foregoing conception of the true aim of a weather bureau. It is not my present purpose, therefore, to enter into an unnecessary argumentative discussion of the scope of a weather bureau's work, but my desire is to emphasize one particular feature of this work, the importance of which claims for it the careful consideration of every employee of the United States Weather Bureau. I refer to the work of original scientific investigation.

The history of nearly all important scientific discoveries shows that they require, not only much labor and perseverance on the part of the investigator, but also the expenditure of more or less money for experimental purposes. The necessary funds have, in some instances, been supplied by the investigators themselves, while in others they have been supplied by moneyed men who were interested in science, or by public institutions. It is therefore plain that there are two conditions which must be fulfilled in order that progress may be made along this line. These conditions are: First, there must be independent thinkers and investigators; secondly, there must be appliances with which the investigator may conduct his experiments.

If there is a dearth of scientific investigation on the part of employees in the Weather Bureau, I do not believe it is because the first condition named is not fulfilled. It is my belief that not only at the central office, but also on station are to be found employees who have original ideas, and whose ideas, if developed, would in many cases redound to the advancement of meteorology and to the public usefulness of the Weather Bureau. Yet these ideas continue, year after year, in the embryonic state. Is this not due to the fact that the second condition which we have laid down is not fulfilled in our Bureau? It would be difficult, if not impossible, to find throughout the enlightened world to-day a class of men who receive less pecuniary compensation for their labor, when the character of this labor is considered, than do employees in the Weather Bureau. And I maintain that so long as the average salary in the Weather Bureau remains about one-half that received by the average university professor, original scientific investigation by Weather Bureau employees to an extent and of a character commensurate with public demands will always remain without Government aid an impossibility. The writer has himself, during the past few years, spent a small portion of his salary in purchasing apparatus for experimental purposes, and no one will be surprised to learn that he was finally forced to abandon his experiments because the equipment was entirely inadequate.

It seems to me that the time is now at hand when we, as representatives of an important scientific bureau, should take concerted action to secure the funds necessary to fully develop this important feature of our work. Nor do I believe that this will by any means prove a difficult task. In fact, I wish to say plainly that, while I do not maintain that we have been altogether neglectful in this direction, whatever of dereliction may have existed is chargeable to no one except ourselves. The Chief of Bureau and his scientific corps have undoubtedly encouraged original thought and endeavor in every way practicable. It would be presumptuous to suppose that our legislators in Congress would fail to perceive the ultimate economic value of such an appropriation. It is incredible that a Government which expends annually about $1,000,000 for the maintenance of agricultural experiment stations, should hesitate to foster analogous experimental work in the Weather Bureau.

Of course such funds should be equitably distributed and judiciously used. It is beyond my province here to discuss at length ways and means whereby this might be accomplished. The experience gained by our Government in handling agricultural experiment-station funds during past years should make it possible to devise a system which would prove in every way satisfactory. However, in order to more fully define my attitude in the matter, I should say that some important features which should be incorporated in such a system are:

I. The central office should have full control of the funds and general supervision of all investigation.

II. The funds should be distributed annually only to such employees as indicate a desire to conduct investigations under the following conditions: (*a*) The investigator should be able to show that he is not proposing to duplicate previous work, i. e., that his ideas are original; (*b*) his work should be designed toward the advancement of meteorology; (*c*) his investigations should be conducted outside of regular office hours, and not in lieu of any other official duties; (*d*) he should render a strict account of all funds expended. The sole incentive to his action should be the thirst for knowledge and the desire to promote the public usefulness of the Weather Bureau by scientific discovery.

A practical system embodying these features may be briefly outlined. A committee, or board of supervisors, should be appointed at the central office, consisting, perhaps, of the editor of the Review and the chiefs of divisions, with the Chief of Bureau as chairman, to pass upon all applications and to make an equitable distribution of the experiment fund. At the beginning of the fiscal year, when the fund becomes available, a circular should be issued to all employees of the Weather Bureau, naming the amount of the fund and stating that the committee is prepared to consider applications from any who desire to conduct experiments under the conditions named above. A reasonable length of time, say thirty days, should be allowed employees to prepare their applications, after which time no applications should receive consideration until the beginning of another fiscal year. This would make it possible to inform each investigator definitely as to the funds which could be allowed him for the fiscal year, and thus enable him to shape his work accordingly.

Upon the receipt of the circular from the committee, each employee desiring to pursue any line of investigation should carefully prepare a lucid outline of his proposed investigation, clearly indicating the lines along which he proposed to experiment, the results sought, the equipment already on hand, if any, and the additional equipment which would be necessary during the fiscal year; these papers to be forwarded to the committee for consideration. In passing upon applications the sole criterion should be originality. Too great care could not be exercised by the committee in avoiding prejudices arising from personal opinions as to the feasibility of the investigator's ideas. It would be necessary to constantly bear in mind the fact that discovery necessarily implies an advance beyond present knowledge, and often the upsetting of generally accepted conceptions. The broadest liberality should be exercised, and every employee who has an original idea should be given an opportunity to develop it regardless of its apparent merit or otherwise. All applications having been passed upon, the rejected applicants, if any, should be fully informed regarding the grounds upon which their applications were rejected, and references should be cited, when practicable, to show that the same line of work had, in all respects, been previously carried out by others. The funds available could then be equitably distributed among successful applicants. At the end of each fiscal year, each investigator should render a strict account of all funds expended, and make full report of the progress of his work. Results obtained, whether positive or negative, should be summarized. These would naturally be published in the annual report of the Chief of Bureau. An important discovery might, however, be at once announced in the Monthly Weather Review. An investigator who failed to obtain satisfactory results after a reasonable length of time should be required to discontinue, at Government expense, the particular line of investigation in which he was engaged.

While the plan indicated by the foregoing outline might be improved upon in actual practice, no thoughtful person will look for a system altogether free from objections. An objection which is sometimes unthinkingly opposed to schemes of this character is that many investigators would spend greater or less sums of money without achieving any valuable results. This objection is as astonishing for its lack of forethought as it is for its complete absence of foresight. It is eminently worthy of the mind which is "penny wise and pound foolish." Every well-informed person knows that the few scientific discoveries made by the great army of investigators in the past have afforded a manifold return for all the money and labor expended. Should any such system as that which is here proposed be inaugurated in the Weather Bureau, it should be expected that discoveries will be "few and far between:" but does anyone doubt that a few new ideas added to our present relatively sparse knowledge of meteorological laws will more than compensate for the failure of the majority of investigators?

The work of the Weather Bureau is distributed over a vast territory, extending from the north frigid zone to the tropics. Within this territory are to be found a great variety of meteorological and climatic conditions. A richer field for original thought and investigation could scarcely be found. Some employees are located in close proximity to scientific institutions to whose laboratories and libraries they have access. The study of the physical and mechanical principles which underlie meteorological changes might, in such instances, be studied to advantage.

As one deeply interested in the progress of the work of the Weather

Bureau, I will herald with gratification the day when each and every employee has some meteorological problem, however simple it may appear, in which he is so much interested that he can not refrain from devoting to its solution a liberal share of his spare time and thought; for I believe that this will mark the beginning of a period of scientific, as well as practical, advance in the service, which will be gratifying to its employees and highly acceptable to the public.

DISCUSSION.

Prof. **ALEX. G. MCADIE**: The trend of modern activity is toward specialization. It is an age of experts, and an expert may be defined as one who can give the right information at the right time to the right inquirer. Assuming that there is need for experts in our chosen field, and that the men are available, how shall we get them? First, offer a favorable environment; second, the privilege of experimenting along given lines.

To illustrate the impetus which favorable environment gives to research and investigation, let me cite the Pacific coast, where we have a profusion of flowers and fruits. Most lavishly does nature offer, under a genial climate, the fairest products of tree and vine. It is because of these favorable conditions that man attempts to develop further types of fruits, flowers, and vegetables. In other lands the man who makes two blades of grass grow where previously but one existed does well, but here these horticultural wizards give the poppy, the violet, and the rose robes more beautiful than dear old mother nature with all her means and generous impulses ever previously gave her wild daughters. To such men the fruits as we know them are but prototypes of a multitude to come of rarer excellence and higher character. As children we long to be Napoleons, winning battles in which men are mowed like the grass of the field, but as men we would fain be Burbanks, taking the most neglected and contemned weed, downtrodden and despised of all, a veritable Ishmael of the field, and, recognizing its one redeeming trait, lift it to a stage of usefulness. We might well envy these wizards of horticulture who win such victories were it not that our own field of work is equally fascinating. A raindrop seems a commonplace affair, but, if we knew all, the universe is not more marvelously held together. And where is there a more entrancing life history than that of the water vapor as it rises, the breath of ocean, from the level of the seas to the realm of the clouds, journeying hither and thither, imprisoned in banks of fog, or sailing high in summer skies, enjoying long its freedom, and when at last it falls, unlike all other fallen spirits, it blesses, bringing with it as playfellows to earth the rarest lights of heaven!

What do we know of the physical processes of cloudy condensation in the free air? Try to make a cross section of a fog bank and chart the temperature distribution, using only mercurial thermometers. You will realize that instruments much more sensitive to heat radiations are necessary. Our hygrometers likewise give but a very general integrated indication of the work that is done—of the energy that is utilized. The heat of vaporization and the heat of fusion are not clearly indicated by our present instruments. In fact, we are in the predicament of a maker of fine watches who is restricted to the use of a crowbar and sledge hammer; very serviceable tools for some purposes, but not for repairing delicate hairsprings or fine balance wheels. Has it ever occurred to you that we who live in the twentieth century and read in the morning's news the temperatures and rainfalls over a continent would be considered "all knowing" by the people of the seventeenth century; for the thermometer was unknown before Galileo's time, and the barometer was not invented until 1643? And what will the people of the twenty-first century know of atmospheric processes? Will apparatus keeping faithful account of the energy from all incident radiations be in general use? Will radiations of all wave lengths be accounted for each day? Will the thermopile, the radio-micrometer, and the bolometer seem as crude and clumsy to these coming ages as the philosophical apparatus of the nineteenth century now seems to us?

We know relatively less about radio-active substances than the philosophers of Franklin's time knew about heat. It is but a few years ago since Becquerel called attention to the action of the uranium compounds under sunlight. Elster and Geitel, together with Zeleny and T. C. R. Wilson, have shown us that electrified bodies lose their charges under the influence of certain radiations, and that an ionizing of the surrounding air may thus be effected. It is said that the ultra violet rays of sunlight ionize the upper air strata, and that water vapor condenses more readily on negative than on positive ions. What great practical applications of cathode and Röntgen rays are yet to be made in the field of meteorology? Who will utilize the radio-activity of the thorium compounds, or those unearthly substances, radium, polonium, and actinium, which have but recently been isolated by Professor and Madame Curie?

I am not competent to speak of the recent advances in theories of electro-chemical change. The work of Prof. J. J. Thomson on electrons, those minute associates of the atom, is, however, too significant in connection with the ionization of air at atmospheric pressure to be passed over without reference before a body so deeply concerned as this convention is with all questions relating to the formation of the raindrop.

Problems connected with gaseous dissociation and the passage of electrical discharges through air, under different conditions of pressure and temperature, are now in the laboratory stage, and we are beginning dimly to see what a wonderful chain of physical processes is involved in an electrical discharge through air. Let us hope that it will not be long before the meteorologist applies practically these new discoveries. In a line of work more familiar to the speaker, viz, that of atmospheric electricity, there is room for much investigation. There are problems connected with the lightning flash, and, indeed, with every form of electrical discharge in air, which can be partially solved because of the experiments of Hertz, Lodge, and others upon resonance in Leyden jar circuits.

A few weeks ago a member of this convention read of a patent granted abroad for the use of a coherer in recording distant thunderstorms, and that an instrument based on this principle was in successful operation. It was gratifying to him to know that such an instrument existed, for in one of his notebooks some years ago just such an instrument (so far as can be ascertained) was sketched out.

Wonderful indeed has been the progress in etheric telegraphy, but think what further applications await the meteorologist.

By sheer force of modern methods and apparatus some six years ago Rayleigh and Ramsay dragged argon from the nitrogen of the atmosphere, and since then, by reason of the discovery of argon, how many new gases have been brought to light—e. g., helium, krypton, xenon, and neon. In 1823 Faraday liquefied chlorin. Oxygen was not liquefied until 1877, and nearly every chemist twenty years ago would have said that the chances were that hydrogen never would be liquefied, but in 1901 Dewar and others solidify hydrogen and obtain temperatures as low as 15° A. to 13° A. (−258° C. to −260° C.). It may well be said that the nadir of temperature is within hailing distance.

When, then, a man who has the hall-mark of investigator stamped upon him asks for such apparatus as in his judgment is needed to carry out a legitimate line of investigation, he should by all means be encouraged, for it is a sure truth that through the labors of such men mankind moves forward, mastering slowly the forces of nature and utilizing for the good of all, energy otherwise wasted.

STUDY OF SKY POLARIZATION WITH REFERENCE TO WEATHER CONDITIONS.

By Mr. L. G. SCHULTZ, *Fort Worth, Tex.*

It would be interesting, by way of introduction to the subject in hand, to begin with a statement of the many theories that have been advanced regarding sky polarization; but in the limited time at our disposal this will be impossible, and so it must be assumed that we all are familiar with the most important ones of these theories as well as with the investigations that lead up to them. An excellent résumé of many of the most important papers that have been written concerning the polarization and color of the sky, together with a comprehensive bibliography of this and relevant subjects by Dr. N. E. Dorsey, of the Johns Hopkins University, was published in the Monthly Weather Review for September, 1900; and the extent of our present knowledge regarding sky polarization is fully shown in this article.

We all know that if a beam of ordinary light be made to pass across a dark room its path is visible at all angles of observation because its light is scattered by being reflected and re-reflected an infinite number of times by the myriads of small particles of matter that lie within it, and that the illumination of the beam increases up to a certain limit as the number of such particles increases. To the unassisted eye such a beam of light presents no special characteristics; but if it be examined with proper instruments in a manner suggested by Professor Tyndall, in the course of his very interesting experiments with light, it will be found that many of the light waves emanating from it are greatly affected by the minute particles of matter with which they come in contact. By using special devices for intensifying the effects that may be observed in nature, Professor Tyndall showed that, while the largest particles scatter light of all wave lengths—that is, scatter white light—the smaller particles scatter fewer waves from the red end of the spectrum, and the smallest ones only scatter waves from the blue end, where the waves are shortest; and he also showed that the light scattered laterally from the finest particles is polarized—that is, the vibrations within the medium through which the light is propagated, instead of taking place in an infinite number of planes, making all possible angles with the plane along which the light travels, as is the case in white light, after impact with the finer particles of matter are constrained to take place in a single fixed plane which makes a constant angle with the original plane of incidence.

When light waves are so constrained to move in a single plane, the plane in which the motion takes places, as well as the angle that it makes with the original plane of incidence, may be measured with a polarimeter; and it is with measurements of this kind that we are chiefly interested in studying the polarization of the sky. The light effects produced in the laboratory on a miniature scale by Professor Tyndall are every day produced on a grand scale in the atmosphere. According to Tyndall's law the large particles, composing the dust, clouds, and haze, reflecting indiscriminately waves of all lengths, appear white, while the smallest particles suspended in the atmosphere, reflecting only the shortest waves, cause the clear sky to appear blue. The effects of polarization may, under favorable conditions, be observed with the naked eye, but they can be seen at any time, between sunrise and sunset, by looking at any portion of the sky through a polariscope. The most marked effects will appear in the vertical plane passing through the sun. The maximum polarization occurs at points about 90° away from the sun, so that at sunrise and sunset the light from the zenith is mostly polarized, and at high noon this effect will be observed near the horizon.

When a beam of polarized light passes through a space occupied by a great number of large particles, it becomes partially depolarized by being successively scattered in all imaginable planes; and so it is that the sunlight, which is probably completely polarized in the clear regions of the atmosphere aloft, never reaches us in that condition, on account of the presence in the lower strata of the air of large numbers of coarse particles of matter. But these coarse particles are separated by distances that are very great relatively to the lengths of light waves, so that the light is at least partially polarized even when the sky is completely covered with clouds. It may be stated, roughly, that the amount of polarization in light from the sky is inversely proportional to the number of coarse particles floating in the atmosphere, so that it reaches a maximum on bright, clear days and decreases upon the appearance of dust, clouds, and haze.

These variations, due to agencies within the atmosphere, have suggested the utility of polarimetric observations in studying weather changes; but up to the present day this field of work has received very little attention. During 1873 Prof. E. C. Pickering, now director of the Harvard Astronomical Observatory, in a paper read before the American Academy of Arts and Sciences, showed that the sky was uniformly polarized at all points equally distant from the sun. His observations showed some variations, and these he ascribed partly to errors of observation and partly to real irregularities in the atmosphere, which, he concluded, followed no regular law. It should be noted here that Professor Pickering's investigations at the time were not directed to the study of the meteorological questions involved. During the past three years his experiments were repeated at several of the Weather Bureau stations with a view to studying these variations. The instrument used was practically the same as the one used by him. It consisted of a double-image prism fixed at the end of a flat iron bar. One end of the prism was covered with a cap in which there was a small circular hole just large enough to bring its two images in contact. At the other end of the bar was a heavy iron frame placed vertically with reference to the axis of the bar. To this frame there was fixed a circle graduated to degrees. A brass tube, in which a Nicol prism was mounted, was placed so as to occupy the space at the center of the circle. To the outside of the tube was attached an arm which extended to the graduations on the circle. The end of the arm was graduated to show fractions of a degree, so that when the Nicol was rotated the angle through which it moved could be read to the hundredth part of a degree. The prisms were so adjusted that the images caused by the double-image prism could be observed through the Nicol. When the light impinging upon the former was unpolarized, the two images were equally bright, but when it was polarized one was brighter than the other. In the latter case they could be made equally bright by turning the Nicol; and if the instrument was properly adjusted the angle through which the prism was turned gave the necessary data for determining the amount of polarization of the light.

For making observations the bar carrying the prisms was attached to the side of a heavy wooden frame, with square edges, by means of a bolt and nut. It was free to rotate around the bolt as an axis, and a graduated circle drawn on the side of the frame showed the angles through which it turned. The side of the frame to which the bar was attached was kept normal to the sun's rays by means of leveling screws. With the instrument thus mounted observations were made on points 90° from the sun at sunrise and sunset. It was found that the early morning and late evening were the best times for observing, as the sky was then freest from clouds, and the effect of earth reflections was a minimum in a plane passing through the zenith. Noon observations on points near the horizon gave very unsatisfactory results on account of the great amount of cloudiness at that hour and large variations due to topographic features.

Twenty-three series of observations were made at Walla Walla during the months of January and February, 1899; 35 at Spokane during December, 1898, and March, 1899; 95 at Kalispell during the year 1899, from April until November, and 88 at Fort Worth during the years 1900 and 1901. These observations gave rise to a series of polarization curves that do not agree among themselves. Each station is represented by a characteristic curve. Theoretically these curves should be straight lines, but owing to earth reflection at the lower altitudes the lines dip at the ends. The dip is most marked in the curves for the northwestern stations, where the horizon is broken by lofty mountains. By drawing separate normal curves for the morning and the evening it was found that the polarization in the morning was greater than in the evening. The difference was least at Kalispell and greatest at Fort Worth; but at the latter station the evening observations outnumbered the morning six to one, as station duties interfere with morning observations there. By comparing each series with its appropriate normal curve it was found that variations in polarization were much more irregular at sunset than at sunrise, and that great variations at sunrise were more often followed by atmospheric disturbances than great variations at sunset. Polarization above the normal and increasing was found to indicate settled weather. Abnormally low polarization was usually followed by cloudy weather, and the clouds generally appeared in the portion of the sky where the polarization was weakest.

While making these observations it was found that the polarimeter may be used to good advantage in cloud observations. Even on cloudy days, with the sky entirely overcast, it would indicate whether the clouds were dissolving or growing denser by showing an increase or decrease in the amount of polarization. Patches of cirrus and cirro-stratus clouds were often watched for hours at a time, and frequently the polarimeter indicated that rapid changes were taking place, while to the naked eye the clouds appeared to maintain a constant size and shape. In showery weather, when the air is heavily laden with vapor, even though the amount of cloudiness be small, the polarization is weak. With fair-weather conditions, even with the sky thickly dotted with heavy cumulus clouds, the light from patches of clear sky is highly polarized.

DISCUSSION.

Professor **ABBE.** I think the few of us who have tried polarization work ought to compliment Mr. Schultz on doing a very nice piece of work. He actually invented and made his own instrument, and now has worked with it apparently for three years and has got some very good comparisons between his results and the weather, which is a new feature. There are several published German memoirs, with notes of observations, and the general conclusion is that there is no immediate, no clear, relation between the weather and the polarization. But Mr. Schultz is striking out in a new path, and I think we ought to wish him good luck.

Professor **MOORE.** I heartily concur in what Professor Abbe has said. Mr. Schultz has outlined, independently, a course of investigation that many others taking up a similar subject for investigation might pursue. It is directly in line with the ideas of Professor McAdie and Mr. Fulton. We are developing some young, bright, vigorous scientists, and I think probably this convention will accomplish something in the way of inaugurating a system whereby they may have support, financial or otherwise. [Applause.]

FOG STUDIES.

By Prof. ALEX. G. MCADIE, *San Francisco.*

"When this mortal shall put on immortality!" Thus did a great logician twenty centuries ago express the yearning which comes at times to all earnest natures for a change from the dull things of life to the illimitable, ever-certain freedom of the skies. To a man upon a mountain the baseborn fogs of the valley are ever suggesting change. For he sees these wanderers climbing upward with almost painful progress, now falling, now rising on the mountain's flank, until fairly on the peak for a few brief moments they rest, and then, springing free, they spurn the lower hills, and, as full-fledged clouds, pass forever away. Their shadows only, like the memories of departed worth, remain upon earth.

"Fog," says the traveler, "is an unmitigated nuisance." "Fog," says the mariner, "is the shadow of doom." "Fog," says the aerophysicist, "is the first step in rain making, Nature's significant hint to man to follow more closely the process of cloud building, and to peer into the seeming mysteries connected with that Protean element, the water vapor of the atmosphere."

The alchemist sought to transmute the so-called baser metals into precious ones. The chemist to-day, more sure of his ground, changes the form even of the most refractory gas into a liquid or solid. Thus hydrogen at a temperature of −255° C. is a white solid substance. This change of form we are told has been accomplished by three different processes, which may be called, respectively, vaporization cooling, work-expansion cooling, and free-expansion cooling. To change the vapor of water to water or to ice requires a much less range of temperature, and we frequently find under natural conditions these transformations occurring.

There are places on the coast of California where the soft sea breeze stirs only the leaves of the lemon and orange trees. There are other places on the same coast where the wind from the ocean bears to the land a bank of snow-white water vapor. With almost clock-like regularity in the vicinity of the Golden Gate on summer afternoons the velocity of the wind rises to about 22 miles per hour and through the Gate comes a solid wall of fog, averaging 1,500 feet in height and causing a fall in the temperature to about that of the sea, namely, 55°. The topography is such that sharply defined currents form in the lowermost strata of the air. From the summit of Mount Tamalpais one looks down westward upon the broad expanse of the Pacific; to the south, beyond the Sausalito hills, a narrow passage of water connecting the Bay of San Francisco with the ocean, and to the east the entrance to a great valley, 450 miles long and 50 miles wide. It is no unusual thing on a summer afternoon to have within a distance of 50 miles in a horizontal direction a difference of 50° in temperature, while in a vertical direction there is often a difference of 30° between sea level and an elevation of 2,500 feet. The conditions prevailing in winter, when tule fog forms in the great valleys and drifts slowly seaward, are very different from those prevailing in the summer, when the sea fog is carried inland; but even in winter it is to be noticed that the temperatures upon the foothills and mountain peaks are from 4 to 6° higher than in the valleys. An illustration of this may be found on the mornings of December 5 and 6, 1900. The temperature at sea level did not exceed 45°, while at an elevation of 2,000 feet or more the temperature at the same moment was about 60°. As a type of summer fog, August 10, 1901, may be instanced. (See plates I and II.)

The object of this paper is to emphasize the point that fog may be considered as a problem in *air drainage*, just as frost may be so considered. The invisible vapor becomes visible either as cloud, fog, or frost, and our problem is to study and control, if possible, the expansion and compression of the aqueous vapor near saturation temperature. Omitting the changes in pressure—for with diminished pressure comes vapor expansion and cooling—we are to concern ourselves chiefly with such temperature changes as occur near the earth's surface. The cooling may be effected by an ascensional movement, or by contact, with the relatively cool water surface in the case of summer fog and with the land which has been cooled by rapid radiation at night in the case of the tule fog, or by mixture.

It is probable that the last named is the more active agency in the production of the fogs near San Francisco, inasmuch as we have a stream of air and vapor at a temperature of about 55° F. injected into a mass of air and vapor rather quiescent, as a rule, at a temperature of 90° F. It is believed that the fogs shown in the accompanying illustrations result from the sharp temperature contrast at the boundaries of certain air currents and that the contours of the land play an important part in originating and directing these drafts.

Recently there have been several excellent articles in the Monthly Weather Review on "Rainfall from convectional currents and the theory of the formation of precipitation on mountain slopes." The equations given in these articles can in the main be applied effectively in the discussion of these fogs of the Golden Gate, remembering that instead of a vertical flux we have to deal with a horizontal flux. It is difficult to study "in situ" the cooling of ascending air; but under

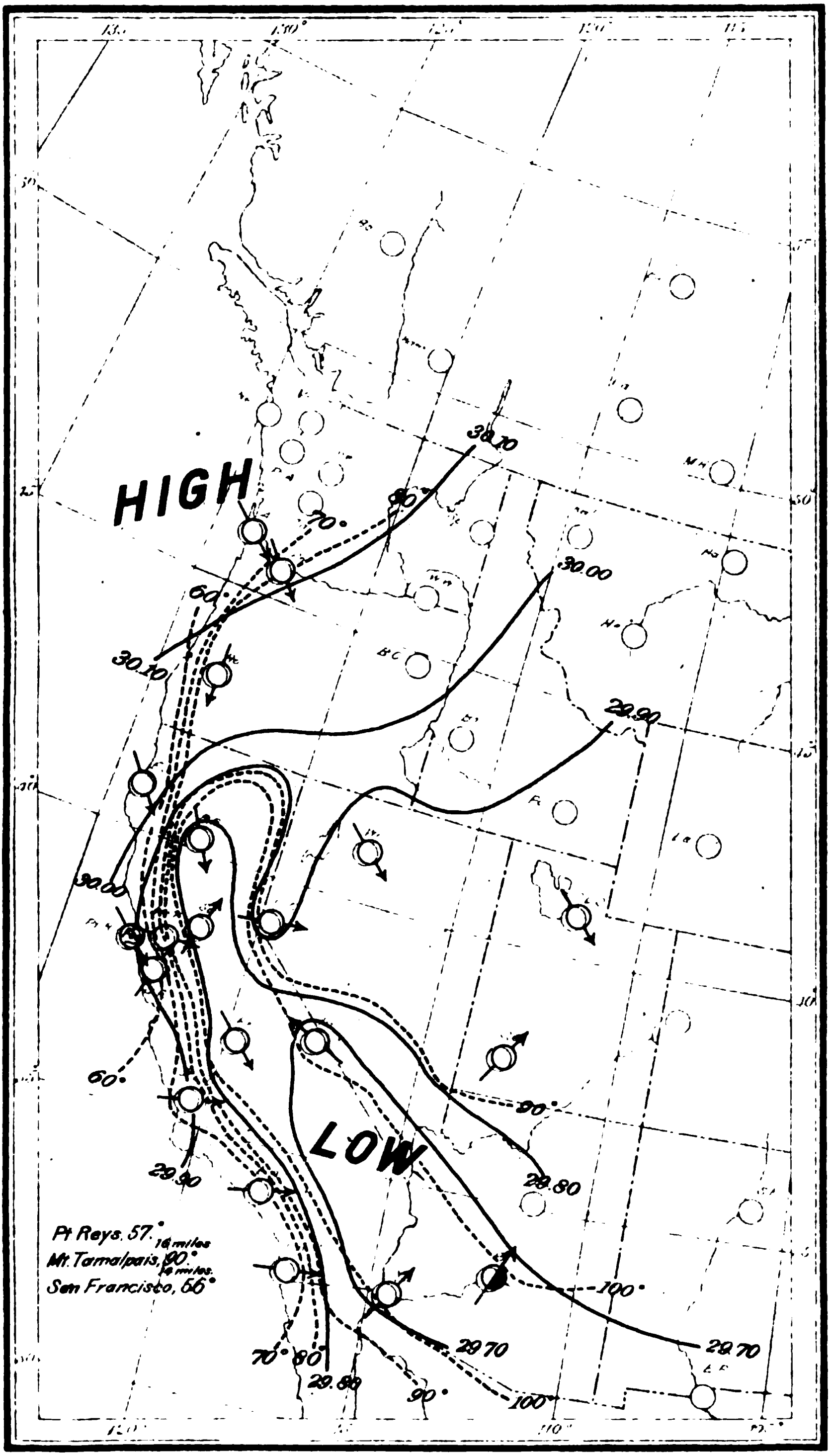
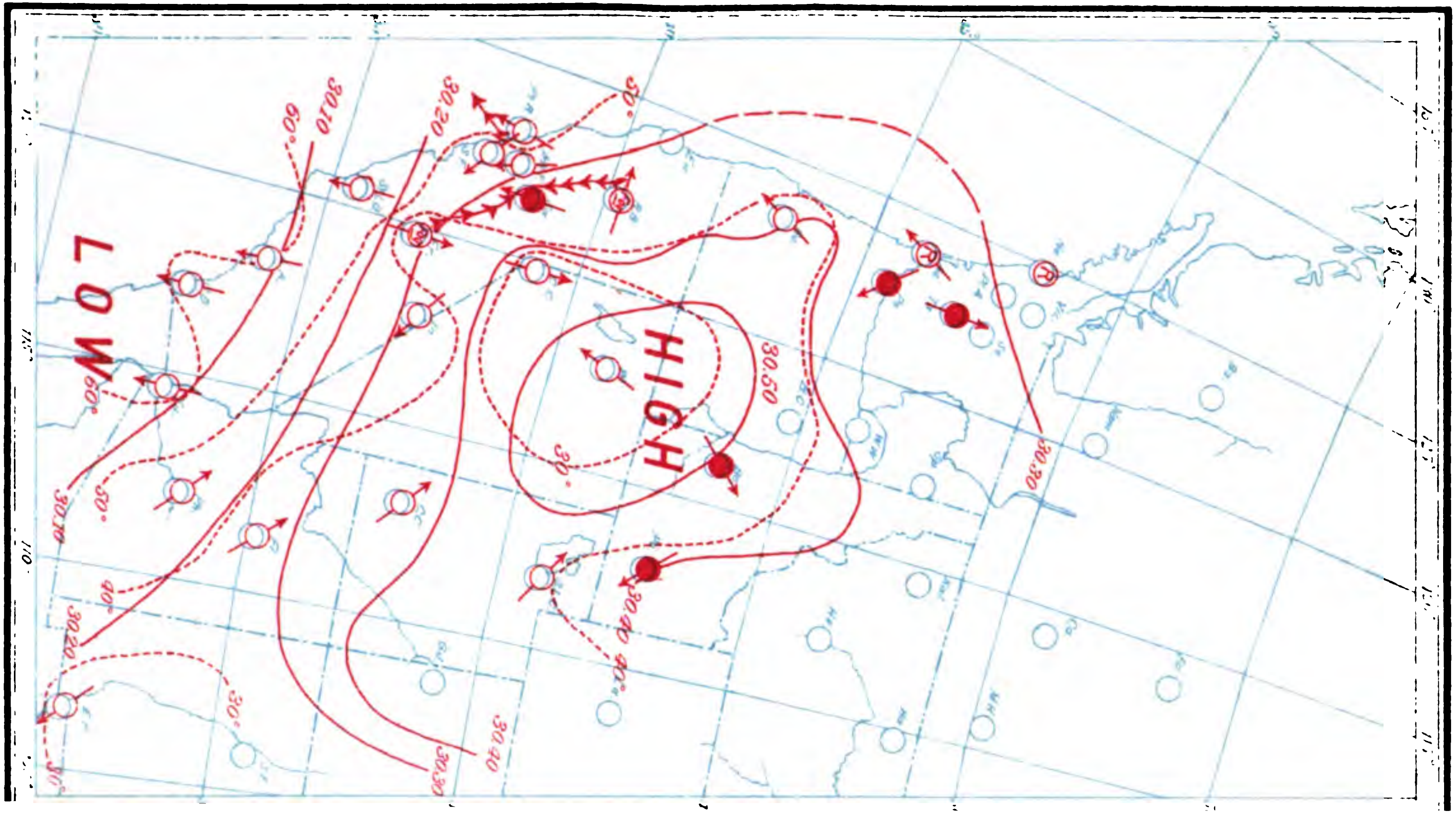


Plate I. Pacific Coast Weather Map, August 10, 1901, 8 P. M. (75 meridian time), showing summer fog formation.

Plate II. Pacific Coast Weather Map, December 5, 1900, 8 A. M. (75 meridian time), showing winter fog formation.



such favorable conditions as exist near Tamalpais the effects of any stoppage or slow motion of the horizontal currents might be investigated even as they occur. It is plain that such discussions are bringing us nearer to an understanding of the processes at work in the making of the raindrop.

Thus far we have considered only questions of formation, but almost of equal importance to man are the questions dealing with the dissipation of fog. If you will study statistics relating to marine disasters and also railway disasters, you will be impressed by the frequency with which the word fog appears as either the direct or contributory cause of the accident. Even if we were able to dissipate fog only within a distance of a few hundred feet around a fog-bound vessel, many an accident would be prevented. It is true that at present the problem appears like attempting to cut away a snow drift with a small shovel. But rotary snow plows to-day accomplish what years ago seemed well nigh impossible; and I do not believe we are over sanguine in hoping that the time will yet come when on large vessels and at certain crowded railway termini some effort will be made to dispel the fog. Dr. Lodge has suggested various methods, of which may be mentioned filtering, clarifying, recondensing, calcining, and electrifying; and with some of these methods there is little difficulty at present in removing from limited spaces fog, smoke, or dust.

On February 22, 1901, a Pacific Mail steamship, the *Rio de Janeiro*, almost within speaking distance of the land, struck a reef in what is thought to be a well-protected harbor. Within twenty minutes the vessel had disappeared from sight with 130 of the 210 persons aboard. The low-lying land fog had caused the vessel to come to anchor about 6 o'clock on the preceding night. At 4 a. m. the fog lifted so that the lights of the Cliff House could be seen; but after the vessel started the fog closed down again and the pilot steered by whistle. Within an hour or two after the accident the fog had dissipated. It does seem that we have here a case in point where the dissipation of the fog for even a few hundred feet around the vessel would have enabled the pilot to locate his position and change the course of the ship sufficiently to insure safety.

The following notes describe the fog pictures accompanying this paper. (See plates III to VIII.)

No. III. *Fog pyramid.*—This photograph was made by the writer July 30, 1900, at 7.15 p. m. The conditions were normal so far as temperature, humidity, and wind go at Mount Tamalpais. The sea-level temperature was approximately 58°; the temperature at a height of 2,500 feet about 62°; the temperature at Point Reyes was about 54°, and this may be taken to represent the temperature of the water. The wind at San Francisco was west, at Mount Tamalpais south, and at Point Reyes light southwest. The view in the foreground is the town of Mill Valley. The apex of the fog pyramid was (it is estimated) about 5 miles from the camera. The fog in the background overlies the Golden Gate and the Bay of San Francisco. The formation is peculiar, and it should be noted that the land under the fog pyramid is level, and the uplifting of the fog is not due to the existence of foothills at this point.

No. IV. *Sunset in sea of fog.*—This photograph was taken in August, 1900, and represents the last view of the sun over a stretch of fog extending westward not less than 30 miles. I waited until I thought the sun had set, but was evidently some seconds ahead of time. The fog filled the valleys to the north and west of the mountain. The general elevation of the upper surface of this fog was about 2,000 feet above sea level; the elevation of the point of view about 2,500 feet.

No. V. *Helmholtzian fog billow.*—This represents a close view of a fog mass foaming as described by von Helmholtz. See his Memoir on Atmospheric Movements, read before the Royal Prussian Academy of Sciences at Berlin, 1889. Another photograph was made showing the condition of this billow after an interval of one minute.

No. VI. *Fog rising and changing into cloud.*—This photograph was taken about 9 o'clock on a morning in September, 1900. In the far distance is seen San Francisco, 14 miles in an air line from the camera. The morning was showery, with fog or cloud resting on the flank of the mountain. The whole mass gradually rose, the showers ceased, and the day was very pleasant. It may be noted that the visibility was very good. The writer recalls distinctly seeing a point on the coast south from the observatory about 30 miles.

No. VII. *Fog billows at Mount Tamalpais.*—This photograph represents the upper surface of fog. As has been pointed out in various papers (see Monthly Weather Review, 1900 and 1901), at a height of from 1,500 to 2,000 feet on summer afternoons a blanket of fog stretches through the Golden Gate and over a large part of San Francisco Bay. It has been found that under such conditions the temperature just about the fog may range from 75° to 90°, while at sea level and in the fog the temperature is about 55°.

No. VIII. *Fog surges.*—This view especially illustrates the air drainage of the district. A strong westerly wind carries the fog up over the Sausalito hills and down again into the canyons and valleys. The current has sufficient impetus to recurve and splash upward when meeting other currents or when deflected by the topography. The houses in the foreground to the left of the rain gauge show the town of Mill Valley.

DISCUSSION.

Professor **BIGELOW**. I would like to ask Professor McAdie one question. He stated very distinctly that the formation of these fog banks was due to three causes, either singly or interacting, namely: Vertical conveyance, contact of currents, and mixture. The problem of mixture, under scientific treatment, has begun to show that on the whole the amount of precipitation from intermixing is rather slight; and while I have always been inclined to think myself that this process of mixing has a great deal to do with our cloud formation under different circumstances, and thus have found myself in conflict with the theoretical statements especially drawn up by Von Bezold, I want to ask Mr. McAdie how much he knows about the fact that mixing does occur, and its effect in producing these fog banks.

Professor **MCADIE**. I am sorry to say I know very little. That is the place to make experiments and find out.

The **PRESIDENT**. We have a number of guests with us, and we shall be pleased to have them take part freely in these discussions. We have as a guest Mr. Clayton, whom you all know for the excellent work he has done at Blue Hill. It is not necessary for me to say anything about his reputation as a meteorologist. The Weather Bureau has always expressed the greatest good will toward the independent work that has been carried on at Blue Hill by Mr. Rotch, with the able assistance of Mr. Clayton. We hope the spirit will move him to say something regarding these problems.

Mr. **CLAYTON**. I have enjoyed the papers this morning very much. Professor Moore's suggestion of observatories in connection with the weather service has particularly pleased me, and I hope very much he will succeed in getting it through. All the papers this morning have been papers on which I would like to say something, but Mr. McAdie's fog results have been directly in line with our observations from the top of Blue Hill. We frequently see at Boston, as well as is seen on the Pacific coast, the rolling in of such fog banks. I have stood on the top of Blue Hill when as far as one could see the entire country was buried in fog, only the tops of the hills showing above. Furthermore, I have thoroughly convinced myself that the fog that comes off the ocean is entirely due to mixture. Fogs occur in almost every case where there is a very cold current that flows off the water while above the cold current is a warm, damp southerly current, plates not [illegible] 10-14-23

usually 10° to 15° warmer, and saturated with moisture. I have watched the process by which it has taken place. I have seen the upper current apparently meet with some resistance, some ascending current set up—as you will see it beautifully illustrated in Professor McAdie's photographs. This column of fog rising into a warm current apparently causes some resistance; it mingles with the warm current and is tipped over and down into the cold air. There mixture takes place immediately and condensation is increased. Intermixture of these two currents goes on until they are churned to the bottom. Condensation, I feel confident, is entirely due to mixture. I have compared the observed conditions of temperature and moisture with Van Bezold's diagram as given in Waldo's Meteorology and have found that mixture of the two currents would produce condensation. I have watched the battle for hours between the fog bank and the warmer current. Almost always the warmer current is driven out. I hope Mr. McAdie can continue his studies along that line, because I think there are a good many interesting problems involved in them.

Professor MOORE. As to the idea of independent observatories, I may remark that we will include laboratories and opportunities for research work. If we come to the time when we can build independent observatories in every city, or the more important cities, I hope we shall be able to add the laboratories necessary for original research, to give our young men the opportunities they are beginning to clamor for.

We have with us, also, to-day Father Odenbach, who, like Mr. Clayton, is a lover of a science devoted to the elucidation of problems that do not attract other people. His voluntary work in making cloud measurements and in kite work at the college near Cleveland was incorporated in our official reports. It was a work of love, and we appreciate it greatly. I should like to have a word from the good father.

Father ODENBACH. I thank you for your kind reception. Like the rest of the body (Society of Jesus) to which I belong, I am always delighted to take up hard nuts to crack, and we try our level best to crack them. I am very much interested in clouds. Perhaps I am saying it in rather broad terms, but in meteorology we are all groping around in the dark, more or less. There is Professor Bigelow, and a great many more in the Bureau, who would like to know something about the motions of highs and lows. One thinks of temperature changes, another of cloud motions. I have a notion that the study of clouds will be found to be one of the keys, if not the key, to the situation. I think that clouds, if we study them carefully for a long number of years, will solve the problem. It is a beautiful study, and always keeps your hands full of work.

Professor BIGELOW. I think the Bureau owes a debt of gratitude to Father Odenbach for his careful and long-continued observations made at the college near Cleveland. This and the work of the Blue Hill observatory are the only instances I know of where an attempt has been made to get at the diurnal motions of the upper strata of the air—in some respects one of our most important problems, because it is difficult to secure hourly observations.

THE PERSONNEL OF THE STATION FORCE.

By Mr. DANIEL J. CARROLL, *Washington, D. C.*

Success or failure in administering the affairs of a great bureau is to be measured not alone by the ability of its head, but as well by the efficiency of its working corps. As with a military or naval commander, so with a civil chief; he may fail in spite of an efficient force, but he can not succeed with an inefficient one. This aphorism is fully indorsed by the present Chief of the Weather Bureau, and he has said that whatever the degree of success accompanying his administration, it must be duly shared by those whose official actions he was appointed to direct, and whose intelligent, efficient, and cordial support it is his pleasure to acknowledge. Since the great body of weather men are station workers, it follows that in any statement concerning the Bureau the preponderant feature must be an account of its station personnel.[a]

NATIVITY.

Ninety-five per cent of the members of the station force are native-born American citizens. Of the foreign born there are from Austria 2, Canada 4, England (proper) 3, France 1, Germany 5, Ireland 8, Scotland 3, and Spain (Cuba) 1.

PREVIOUS OCCUPATION.

Seventy-three per cent of the members of the station force prior to their connection with the meteorological service were either students, teachers, clerks, printers, or farmers, divided as follows: Students, 21 per cent; teachers, 18; clerks, 17; printers, 10. and farmers, 7.

EDUCATIONAL TRAINING.

Forty-nine per cent have had the benefit of college or university training, 35 per cent completed their schooling in high schools or academies, while only 16 per cent have advanced no higher than the common schools and business colleges. Forty-nine per cent of the first-mentioned class (i. e., 24 per cent of the entire station force considered) are college or university graduates, holding the following literary or scientific degrees: A. B., 25; A. M., 12; B. Agr., 1; B. C. E., 3; B. E., 1; B. L., 3; B. S., 30; C. E., 2; D. D. S., 1; LL. B., 6; M. D., 9; M. E. in E. E., 1; M. S., 5; M. S. Agr., 1; Ph. B., 3; Ph. D., 4.

AGE.

The oldest man in charge of station is 67 years of age, the youngest 23½. The oldest assistant is 64 and the youngest 21½. The average age of the officials in charge is 41 years, and the average age of assistants 35.

MARRIED AND SINGLE.

Seventy-four per cent of the station force are married. Of the men in charge, 78 per cent are married, and of the assistants, 70 per cent, an observer of the opposite sex in charge of a regular station of the Bureau (the widow of a veteran "observer sergeant") being omitted in the count.

LENGTH OF SERVICE.

Seventy-nine men (about 25 per cent of the station force) have been in the service less than five years; 34 men have served continuously five years; 81 men ten years; 66 men fifteen years; 35 men twenty years; 16 men twenty-five years; 2 men thirty years; and one man has been continuously in the meteorological service since it was organized. For continuous service at present station the record is: Five years, 65 men; ten years, 19 men; fifteen years, 11 men; twenty years, practically. 3 men.

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[a] For the purposes of this paper, in referring to the "station force" allusion is made to printers, observers, and higher grades. The figures presented are based on the record of June 30, 1901, or result from the departmental census of March, 1901.

STATION SALARIES.

At the close of the last military administration (June, 1891), the highest salary per annum was $1,246, the lowest $480; the average $963. At the close of the first civil administration (June, 1895), the highest salary was $1,800, the lowest $600; the average $1,111. On June 30, 1901, the highest salary was $2,500, the lowest $840, and the average $1,185.

STATION CHANGES.

The greatest number of changes made by any member of the present station force equals 27, or, including first station, 28. The observer referred to has served twenty-eight years. He has therefore averaged one station a year. He has been at his present station since April, 1895.

Eighty-two per cent of the force hold existing assignments by selection made by the present head of the Bureau; and as showing the wisdom of such selections, the satisfaction or discontent arising therefrom, it may be stated that 85 per cent desire no change of station, and subtracting the number wishing a change for purely personal or domestic reasons—that is, without dissatisfaction as to geographical location—92 per cent will represent the degree of contentment. Of the assistants less than 15 per cent desire a change as assistants.

A few years ago the goal was an assignment to duty at the Central Office. The betterment of the station force in point of salaries and the broadening of its sphere of importance have altered the design of the ambitious. This is demonstrated by the fact that but 15 applications (11 from assistants and 4 from officials in charge) expressing preference for duty at the Washington office are on file.

In connection with this subject the importance of Form 4047—Mis., station preference card, should not be overlooked. This card record of preference is invariably consulted by the Chief of Bureau personally whenever a vacancy in the station force is to be filled. The wishes of applicants for change of station are always considered when changes are to be made, and preferences are granted whenever practicable and compatible with public interests. A case in point is one of recent date. An observer filed a card expressing preference for assignment to a certain station. Shortly after the receipt of the card a vacancy occurred at the station named, and orders for the change were issued. Upon the receipt of instructions to proceed to his new station the employee reported that his preference was to remain where he was. His attention was invited to his card request, which he had neglected to amend, and it being impracticable to alter the plans of the Central Office the orders for the change stood. However, a few months later the observer was returned to the station of his choice.

The average number of changes (including office and station force) ordered per annum by the various chiefs of the service from January, 1873, to June 30, 1901, was:

Myer (during $7\frac{8}{12}$ years), 467; Hazen (6 years), 405; Greely ($4\frac{6}{12}$ years), 245; Harrington (4 years), 122, and Moore (6 years), 122.

APPOINTMENTS, PROMOTIONS, ETC.

During the six years ended June 30, 1901, the average number of appointments per annum was 26; promotions, 60; reductions (for discipline, 6; without prejudice to the employee, 10), total, 16; resignations or transfers to other bureaus (for this Bureau's good, 2; voluntary, 8), total, 10; discharges (for discipline, 5; without prejudice to the employee, 1), total, 6; deaths, 2.

ENTRANCE EXAMINATIONS.

As early as 1870, years before the passage of the civil-service law, mental examinations were required of applicants for enlistment in the meteorological service. The earlier entrance examinations embraced grammar, geography, arithmetic, spelling, and penmanship. As time passed the scope of the examinations was gradually increased by Chiefs Hazen and Greely, and history of the United States was added. It has been still further broadened under the civil authorities until the following scope has been reached:

Subjects.	Weights.
Spelling	10
Arithmetic	10
Penmanship	5
Copying from rough draft	10
Meteorology	30
English composition	25
Geography	5
Algebra	5
Total	100

Since March, 1900, the age limitation has been 18 to 30 years. Prior to that date it varied. First it was 18 minimum, with no maximum limit; then 20 minimum, with no maximum, and later, 20 minimum to 45 maximum.

The reports of the Civil Service Commission show the popularity of the position of Weather Bureau observer, as indicated by the large number of persons examined for that position compared with the number examined for other scientific places paying about the same initial salary. The station force was classified in 1893. In that year, when plans were perfecting, few examinations for entrance were held. In 1894 42 persons were examined; in 1895, 44; 1896, 34; 1897, 37; 1898, 99; 1899, 230, and in 1900, 314. It will be noted that up to 1898, inclusive, a period covering five years, 256 persons were examined, while in the last two years, 1899 and 1900, the number was 544—more than double the preceding total.

PROMOTION EXAMINATIONS.

In presenting this feature, station and Central Office employees have been combined, separation being impracticable.

Of the 288 employees subject to these examinations, 105, or 36 per cent, have been examined.

The highest and lowest ratings obtained by those that passed (reexamination included) are:

	Highest.	Lowest.
Grammar	99	70
Arithmetic	100	70
Elementary meteorology	100	70
Algebra	100	73
Trigonometry	100	84
Physics	99	70
Astronomy	98	76
Botany	96	86
Advanced meteorology	97	72

The supervising examiner regards as passable in any subject a rating of 70 to 74; as fair, 75 to 79; as good, 80 to 84; and as excellent 85 and above.

The following tables will show, by subjects, the number examined, the number passed, and the number failed:

ORIGINAL EXAMINATIONS.

	Examined.		Passed.		Failed.	
	Collegian.	Noncollegian.	Collegian.	Noncollegian.	Collegian.	Noncollegian.
Grammar	55	50	47	37	8	13
Arithmetic	55	50	39	34	16	16
Elementary meteorology	55	50	53	42	2	8
Algebra	29	13	19	10	10	3
Physics	32	14	26	12	6	2
Trigonometry	12	0	10		2	
Astronomy	5	0	5		0	
Botany	5	0	5		0	
Advanced meteorology	5	0	4		1	

REEXAMINATIONS.

Grammar	3	8	3	2	0	6
Arithmetic	14	10	11	6	3	4
Elementary meteorology	1	2	1	2	0	0
Algebra	6	1	5	1	1	0
Physics	4	0	4	0	0	0
Trigonometry	0	0				
Astronomy	0	0				
Botany	0	0				
Advanced meteorolgy	1	0	1		0	

ESPRIT DE CORPS.

One of the military chiefs of the meteorological service gave it as his opinion that—

> **Our meteorological work all depends upon an accurate and continuous record. To get these conditions observers must be carefully trained and must be held with an absolute control. This makes a military organization indispensable.**

Another army officer of long experience in both the military and civil meteorological services said:

> **Good soldiers, as also good civilians, do not need constant application of corrective measures. Get good men and there will be no need of military discipline. Get worthless men and all the military discipline in the world will not rid them of their worthlessness. The prime factors of an observer's make-up are obedience, honesty, and reliability.**

The three factors mentioned by the latter official are preeminently the controlling factors in this Bureau.

Neither pestilence nor storms have availed to stampede the station workers of the Weather Bureau. Whenever circumstances require, we may confidently look for a repetition of that display of courage and fidelity on the part of the station force which occurred in the summer and autumn of 1897, when the dreaded yellow fever was so prevalent as to render perilous the positions of many of our men, who with great zeal and faithfulness remained at their posts, held there solely by a sense of duty to the public. The conspicuous conduct at the Galveston station on the occasion of that terrible hurricane in September, 1900, was but another illustration of what may be expected of our station force in responding to the call of duty.

When the telegraphic report of an observation is received late or not at all, the station is called on for explanation. During the calendar year 1900 more than 83,000 telegraphic reports of observations were required to be transmitted to the Central Office. During the same year but 26 calls for explanations were necessary, and less than 25 per cent of that small number of calls were unsatisfactorily explained.

This marked punctuality in the handling of telegraphic reports is as gratifying as the result of an inspection of the last semiannual report on the accuracy of work on the more important meteorological forms. Out of 173 Forms 1001, 38 per cent were literally correct; of 151 Forms 1022, 89 per cent were likewise correct; of 45 Forms 1026B, 62 per cent; of 45 Forms 1026T, 71 per cent, and of 86 Forms 1070, 64 per cent.

There are few stations that have not been inspected during the past two years, and the high commendations elicited by these inspections have greatly outnumbered the few slightly unfavorable reports.

As in the old days, so in these, an accurate, continuous, and complete system of observations and reports is easily maintained, whether based on work performed in the metropolis of the country or at the most isolated point. The marked devotion to duty of the old observer sergeant, great as it was, regardless of his location, has found its counterpart in the zeal of his civilian successor.

The older men of the Bureau will recall with satisfaction the words of the military chief who, in the name of the Secretary of War, made the formal transfer of the weather service to the Department of Agriculture. At the time of the transfer he said:

> The various duties of the Signal Corps have brought the present Chief Signal Officer, while serving as a subordinate, into unusually close relations with the enlisted force in almost every section of the continent, from the valley of the Rio Grande to the plains of the Dakotas and Montana, and in the dreary wastes of the Polar regions. Such conditions necessarily develop the character of men, and under these adverse and trying circumstances the enlisted force has invariably performed its duties with rare efficiency and fidelity, and it is with great regret that now, after over twenty years of service, covering the prime of his manhood, he severs his official relations with a branch of the Signal Corps which has been charged with duties always entailing responsibility and anxiety, fraught often with danger and hardship, and which have proved to be of benefit to the country and an honor to the Army.

If this commendation was merited, it is to be noted that 61 per cent of the present station force were then in the enlisted corps of observers and came within the purview of those remarks. Thirty-five per cent of the present force joined the Weather Bureau after its transfer to the Department of Agriculture. This blending of the old and new has yielded a body of men whose animating spirit is scarcely equaled in any other branch of the public service, and certainly not anywhere surpassed.

CHINOOK WINDS.

By Mr. E. J. GLASS, *Helena, Mont.*

Along the eastern slope of the Rocky Mountains in winter, with a temperature below zero and the ground covered with snow, a peculiar mourning or whistling sound is most welcome to the ear. This sound acts like magic on its hearers. It causes the business man to lose a moment in his calculations, the clerk to pause in his routine, and the stockman to listen intently. It announces the advent of the chinook wind. This wind is more welcome to stockmen perhaps than to any other class of business men. The stockmen know that the high velocities which generally accompany these winds will first blow the snow from the hills and high ground into the ravines, then the temperature will rise, usually above 40° F., and occasionally above 50° F., and clear the ranges so the stock can find food. The snow is drifted by the chinooks into the deep canyons and ravines. It is slightly melted on the surface by the warmth of the wind, and the water percolating slowly downward gradually converts the mass into solid ice. Unless these drifts be solidified by the thawing and freezing process they can not be depended on for summer use. Thus chinooks serve a useful purpose in the storage of the snow that supplies the water to our rivers during the summer season. The solidification of the snow by the chinook winds, by rendering rapid thawing impossible, prevents the destructive spring freshets in streams and rivers that sometimes occur when the snow lies undrifted over the hills and plains.

Three things are essential to the formation of a chinook wind, viz, a mountain range, an area of high pressure, and an area of low pressure. The area of high pressure and the area of low pressure must be so situated with respect to each other and to the mountains that the wind from the high area into the low area blows across the mountain range. If the mountains extend northwest and southeast, as the Rocky Mountains in Montana do, the direction of the chinook winds will be from the southwest or west.

At Helena, Mont., the barometric conditions accompanying the chinook are as follows, viz, an area of low pressure moving southward along the eastern slope of the Rocky Mountains, its center passing over the northeastern part of Montana; and an area of high pressure central over the region comprising Utah, Nevada, and the southern part of Idaho, the eastern edge of the high extending only to the crest of the Rocky Mountain Range. The winds of the westerly side of the low take the air from the base of the mountains, and its place is taken by air from the upper regions of the high, the mountain region holding back, as it were, the surface air of the high area. The upper region of the high area has a higher temperature than its surface air. In descending the eastern slope of the mountains, the air from the upper region of the high area is further heated dynamically. Its temperature rises to 40° F. or 50° F. and frequently remains stationary at that height for twenty-four hours. The vertical temperature gradients of the area of high pressure must increase up to a certain altitude. However, no kite observations have been taken in the Rocky Mountain districts to verify this fact. The mining town of Unionville, 6 miles south of Helena and a few hundred feet higher, is located at the head of the same gulch in which Helena is situated. Unionville has been observed on several occasions to have temperatures above the freezing point while at Helena the temperature would be 15° F. to 30° F. below zero. During the last part of January and the first part of February, 1893, Helena experienced the coldest weather since the establishment of the station at that point. During this period of protracted cold the air was calm. On the top of the main range of the Rocky Mountains, southwest of Helena and about 15 miles distant, the temperature was above the freezing point. Another instance of the warm air being above the cold in an area of high barometer is shown by the case of one of the eastbound Northern Pacific trains. As the train descended the Rocky Mountains it experienced in traveling 10 miles a rapid fall in temperature from above freezing at the summit to 25 below zero. The change was so sudden as to cause great creaking sounds in the cars, which attracted the attention of the passengers and alarmed them, and they were not reassured until told by the conductor that they were descending into a cold wave on the eastern slope of the mountains.

The clouds usually indicate a chinook several hours before the change in temperature takes place. These clouds consist of small ragged cumulus not stratified in the least and traveling with great rapidity. They generally range themselves in parallel rows, with blue sky between. Sometimes they are black and threatening, but no precipitation occurs. (Illustrations of these cloud effects are given in Plate IX, Figs. 1 and 2.). Many times when the eastern slope of the Rocky Mountains is enveloped in the warm cloak of a chinook the States of Utah, Nevada, and Idaho are reporting zero temperatures. The temperature of the chinook wind can not possibly be classed with the warm weather that accompanies an area of low pressure, as the rise in temperature is not gradual like that accompanying the usual low area, but is sudden. The temperature often changes 20° to 30° in ten minutes, as the thermographs at stations along the eastern slope of the Rocky Mountains show.

Cold waves seldom follow chinook winds, and the temperature generally remains mild for several days or until an area of high pressure approaches from the northwest, reversing the conditions of chinook production. An area of low pressure over the plateau region and an area of high pressure passing southward from Alberta along the east slope of the Rocky Mountains is the opposite of the chinook condition, and it is without fail accompanied by a cold wave—one of considerable severity and one which continues for several days. A good example of this is shown on the weather maps of November 17 to 20, 1900. Chinook conditions sometimes form during summer, but they are of very short duration and difficult to forecast, because the area of high pressure does not remain in summer any length of time over the plateau region. A few examples of chinook conditions can be found on the weather maps of January 14 to 18, 1899; December 21 to 25, 1899; March 5 to 8, 1900; February 24, 25, 1901. These are only a few examples of the chinook winds of Montana. These dates are marked types, and the temperature changes were rapid and accompanied by high winds.

The most beautiful cloud formations are caused by the chinook. They apparently travel eastward rapidly only to disappear and others to take their places. The sky is of a deep blue and very transparent. Mountain ranges 20 miles away look as if they were only 5 or 6 miles distant. It is a quite common thing at the beginning of a chinook for the temperature to fluctuate rapidly, that is, to rise suddenly 20 or more degrees, only to fall as many degrees during the next five minutes and to continue this rapid change for an hour or more before the chinook drives out all the cold surface air.

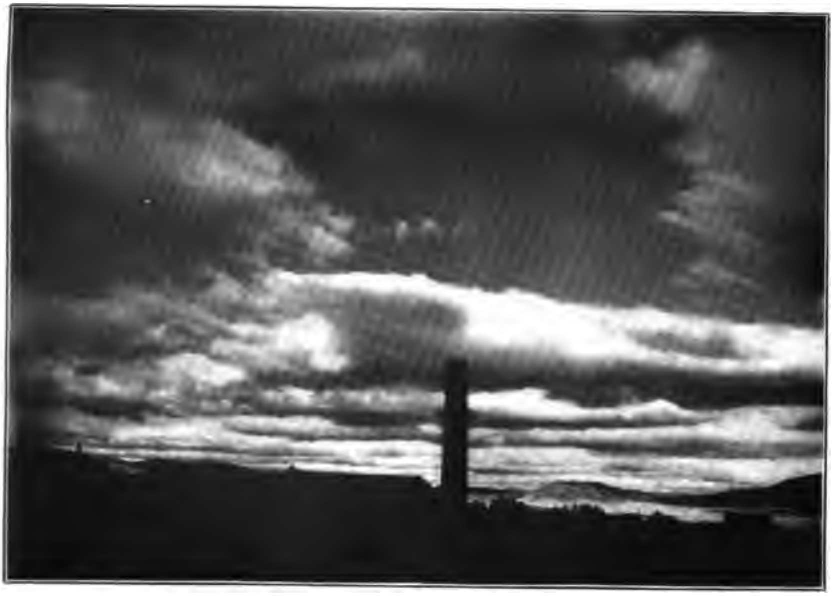

FIG. 1.—CHINOOK CLOUDS.

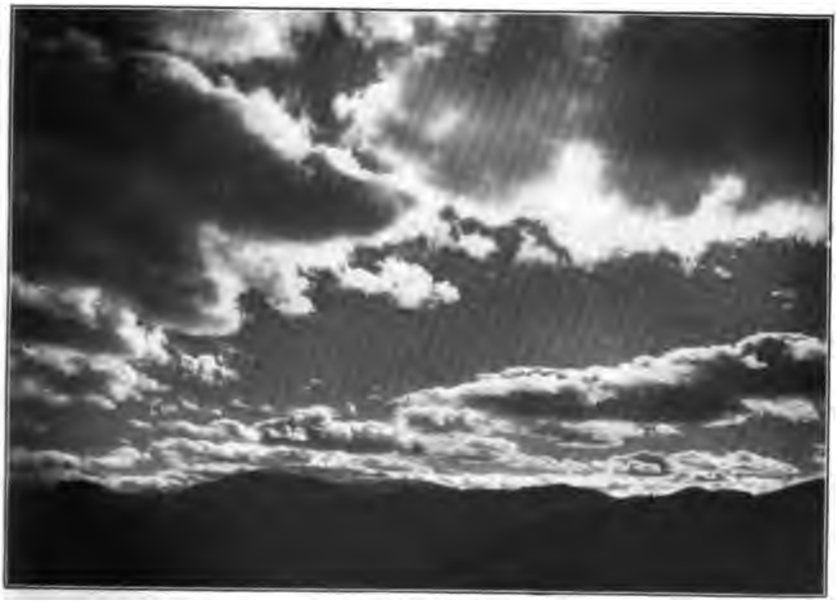

FIG. 2.—CHINOOK CLOUDS.

DISCUSSION.

Mr. Clayton. I think the chinook is an interesting example of a phenomenon, which occurs in other parts of the United States. Of course the chinook wind is very much more marked than the others, but along the Atlantic range and probably along all elevated situations in the United States on the windward side there are slight tendencies to that effect. It is often noticeable on the weather map that it snows at Buffalo and Cleveland some time after it is clear on the Atlantic coast, the descending air being relatively both warm and dry on that side of the mountain. I think this is a good field for those young investigators we have been speaking of, because, it seems to me, it will have a bearing on the local forecasting of the section.

THE FORECASTER AND THE NEWSPAPER.

By Mr. Harvey Maitland Watts, *of the Philadelphia Press.*

Seven years ago, in discussing the relation of the Bureau to the public through the medium of the newspapers, in pointing out how uncertain a medium the newspapers were, a few practical suggestions were made as to how the situation might be improved by certain definite action on the part of the Bureau.[a] That the précis written in

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[a] The communication here referred to as written seven years ago was printed in the American Meteorological Journal of January, 1895, but was written in November, 1894. After a presentation of the facts as to the neglect of meteorology by the newspapers, the suggestion was made that as so little aid could be expected from them we must look to the Bureau for a special effort at illuminating the press, and the communication then continued as follows:

"With regard to the Weather Bureau much can be done along normal lines to improve the situation. The question is hardly one of space. and, without asking for any additional space, there is a way in which the Bureau can be of service to the newspapers, and both directly and indirectly impress itself on all the matter written on weather topics. As a basis for this improved relation, as a very sine qua non, the Bureau should issue a general weather chart (about the size of the Hydrographic Bureau's monthly charts), which could be hung up in every newspaper office throughout the land. This chart should contain a large generalized weather map of the United States: not so large, however, but that enough space be left for letterpress embodying in as simple language as possible the most accurate information on weather lore as it is held to-day. Particular pains should be taken to define the ordinary meteorological terminology. Tornado, thunderstorm, hurricane, cyclone, should be carefully differentiated and explained with reference to the map, which should contain some such general and typical storm on it as the cyclone which conditioned the tornadoes at Louisville on March 27, 1890. On the map also could be shown a typical hurricane from the West Indies, with paths of others that have been charted. In the letterpress several storms could be analyzed and salient facts as to storm formation and movement presented in a lucid manner; for the most important condition of all is that it should be written from the point of view of the nonlearned reader. Such a chart, with all technical subtleties suppressed and arranged so that those who never before knew what a storm was should understand for once, would work a revolution in the average newspaper office. Instead of the blundering use of meteorological nomenclature now the rule, an exact use would set in, and with the chart ever near at hand for instant reference with which to compare some telegraphic dispatch, the general and local weather article would constantly improve. This is the first step. It would be a sort of Piddington's newspaper hornbook.

"Following close upon the chart, to the issue of which attention could be called from Washington, explaining just what the Bureau hoped to accomplish by it, there should be sent out a small pamphlet calling the attention of the newspaper to the importance of printing all the data sent out daily from Washington in connection with the nightly forecasts. Many papers print the forecasts only, but they should be urged to use also the paragraph which gives the general forecast of weather conditions the country over, which, as it locates the 'lows' and 'highs.' is invaluable for reference afterwards. In addition, the newspapers should be asked to print the monthly summaries, most valuable also for reference, and the

1894 applies all the more strongly to-day shows how small the change for the better has been on the part of the newspapers. The Bureau's work has been markedly improved, the character of the general forecast, with its summary reviewing the general conditions, has approached very near to the practical ideal which it has seemed to me should yield the best results so far as its effect on the minds of the people is concerned. Not only that, but the improvement in the explanation which accompanies the local forecast, in which the individuality of the local forecaster has been brought out, has been marked, and, as is well known, the present Chief of the Bureau is not only anxious about, but encourages in every way, such departures from the routine announcement as will make the daily phenomena under discussion more easily understood by the great public he serves. This is clearly indicated in his instructions sent out in 1899, the formal document, well worth quoting to-day, running as follows:

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU,
Washington, D. C., December 19, 1899.

[INSTRUCTIONS NO. 148.]

In order to extend the value of the work of the Weather Bureau, local forecast officials, section directors, and other officials of the Weather Bureau who are authorized under existing instructions to make local forecasts will amplify the local forecasts with particular regard to local interests and the occurrence of local events.

It is desired that the local officials referred to in the foregoing paragraph feel free to express themselves in such terms and so completely as to give to the public the largest measure of benefit to be derived from the Weather Bureau.

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statement of monthly averages (Form 1079, Meteorological), which is a sort of 'monthly forecast.' Few newspapers print all these data now, and if the more important papers the country over were gotten into this procedure, as a matter of course it would be no mean reform. This is the second step in the improvement of the relations of the Bureau with newspapers; and the third step is the question of the reproduction of the weather map daily. Long before this step is taken it is to be hoped that the weather map will come into a more general use among laymen and newspaper men for reference and study, so that it will be intelligible to those who see it printed as well as to those who print it.

"So far as most maps now used in newspapers go they are glaring failures. The chalk-plate process prints a map that simply uses up space and is worthless. It is illegible and meaningless, even if one takes for granted it is understood by the public. The letterpress that accompanies it is too stilted and general in character. There are no mechanical difficulties in the way of reproducing a good two-column map in our great papers, but the trouble comes in getting a good map to reproduce. What is wanted is a distinct, legible map, with the 'highs' and 'lows' accentuated, and only the important stations shown. This is a basic condition, but above that in importance is the explanation, not wooden, which should accompany the map from day to day as it varies, and explain just what it means. There are some who declare, I believe, that no explanation is needed. That is pure fatuity. There never was a greater mistake. Looking at this matter from the inside of a newspaper office, the need of the simplest, primer-like explanation becomes imperative. Without it the map is worthless. A great deal can be said in from 100 to 300 words in small type under a two-column cut and yet not eat into space. But of course all this presupposes a closer relation of the local forecast officials and the newspapers, for some one must prepare the map and letterpress to accompany it, and it can not be done in a perfunctory way, or failure will be the result. This, then, is the third step in the better relations which should exist between the Weather Bureau and the newspapers. Many would make it the first, but one must crawl before one can run. What all newspaperdom needs is a general illumination in weather lore. The local officials do much. Their words often fall on stony ears, and yet in spite of, not by means of, the reporters they get sound weather facts before the people. If all would work together in the way here suggested, a great change would occur in a few years, and the weather articles would no longer be a reproach to the intelligence of the newspapers and a confusion to the readers.

"H. M. WATTS.

"PHILADELPHIA, PA., *November, 1894.*"

In addition to the local amplification of forecasts and the improved character of the general synopsis, which every newspaper ought to print in full, the monthly Weather Review, under the editorial charge of Prof. Cleveland Abbe and under specific encouragement of Professor Moore, has taken on a character that makes it one of the best exchanges that come to a newspaper office, since it is a mine of rich scientific material, of timely and popular interest, which only has to be properly worked by the observers to afford the public much matter of general interest and of a high educational value. While all this is true, an additional seven years' study of the situation created by the relation of the Bureau to the public through the medium of the newspapers, from the double point of view of a student of meteorology as well as a newspaper man, has merely reenforced my earlier convictions. The public as a whole has changed but slightly and is to-day practically ignorant of the fact that the science of meteorology has developed within the past fifty years a body of fact, of theory, and working hypotheses that compares favorably with any other of the natural sciences. On the contrary, the public holds to old and exploded beliefs, folk superstitions, and what not, with remarkable pertinacity, and, since with this attitude a more or less general acceptance of the claims of weather quacks and wonder mongers exists, as a consequence the difficulty of making any headway must be clear to everyone, and this is certainly brought home vividly to anyone who tries to enlighten the public through schoolroom or lecture platform.

For one thing, the terminology of meteorology conveys little to the mind of the average person. The physiographer, in talking of valleys, ravines, lakes, hills, mountains, gorges, deltas, rivers, slopes, is using terms that connote in the minds of most people definite and somewhat familiar ideas, but the unfortunate meteorologist working down from the A B C's of azimuth, barograph, and cyclone to the mysteries of hyetal phenomena and their zoonomic consequences, is in sore straits. Like the philosophers of Laputa in Gulliver's Travels, we have to carry our entire pack of terms on our backs, and can not move glibly in discourse until we have set them all down and explained them one by one to our listeners. This barrier of a not generally understood nomenclature is, of course, not made less by the prevailing confusion over such terms as the public has adopted for its own, such as "cyclone," "tornado," "hurricane," etc., and the whole situation is further complicated since the newspapers—and here I speak by the card, lest equivocation shall undo me—have failed to meet the emergency that confronts them. The rather pessimistic view taken of their intermediary relation between the Bureau and the public in 1894 must be held to-day by anyone familiar with the daily sins of omission and commission—the daily conflict of fake against facts that mark the weather article. Whatever their equipment may be in other particulars, altogether too many newspapers fail to differentiate seriously between quackery and the new science, and unfortunately rather reflect the ignorance of their own environment in the matter of weather and meteorology instead of illuminating it.[a]

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[a] This indictment may seem too sweeping, too general, but while there has been a marked improvement in the character of the special articles on the weather—scientifically accurate and at the same time "interesting"—which the better type of newspapers occasionally print, and while the list of newspapers that represent equipment in this particular is constantly growing, at the same time the errors that occur in the reportorial and editorial treatment of routine weather phenomena are much in excess of what one would expect, considering the accessibility and essential simplicity of the undisputed facts of modern meteorology.

The situation thus created, therefore, by the conditions that exist to-day is an anomalous one and makes the work of the Bureau, despite the admirable efforts of everyone in it to serve the public faithfully, unnecessarily difficult. Being what it is, however, I feel that the plan I suggested in 1894, with certain modifications, still promises the best results, and if rightly applied will meet the state of things that exists in the average newspaper office to-day. And of all the various issues that confront the Bureau to-day none is so fraught with possibilities for good or ill as the use of the newspapers. While the public may be reached in other ways on occasions, it is the daily newspaper's constant, reiterated presentation of the weather three hundred and sixty-five days in the year that is the determining factor in the status of the Bureau with the public. The pressing fact is that without act of Congress or administrative order the daily newspaper is the unofficial agent of the United States Weather Bureau. The question, therefore, is not how the public may be made to grasp the new meteorology through other channels, but how the newspaper can be made the medium of an equipped, illuminating presentation of the weather facts as we know them. What is demanded by the rather unfortunate state of things that exists to-day is an improvement in the work of the unofficial factor in the intercourse between the Bureau and the public—between those who reflect the modern science and those to whom it is still a mystery. No radical improvement can be made in the use of the newspaper, however, unless some adequate idea be gained from the inside as to the actual needs of the average newspaper. A ten years' study of a wide range of exchanges has but doubled the conviction that the improvement of the newspaper as a medium of instruction for the public must proceed along very simple lines. Certain newspapers to-day will print anything, but the only special publication on the weather that tells is that that clears up the matter in hand in such a way that, if the reader never understood the issue before, he will understand it after reading the given article or studying the given map. If the work of the Bureau in this direction is to tell more effectively to-day, "stoop to conquer" must be the motto for all those in its service who come in contact with the public through the newspaper—and this means the newspaper reporter nine hundred and ninety-nine times out of a thousand—and I shall indicate the lines along which I think this policy can make itself felt with greatest practical effect.

I still believe that the Bureau should issue a general informatory chart—the details of which I need not discuss—for use in newspaper offices, to say nothing of its value to public schools. If the issue of such a chart by the Bureau seems irregular and the expense not warranted it can not be too firmly said, in view of the actual, if unofficial, agencyship the newspapers occupy as a vehicle of intercourse between the Bureau and the public, that no stone should be left unturned to add to the equipment of these inexperienced agents who multiply its influence a thousandfold. The Bureau exacts a high rate of service from its forecasters, and it is continually planning for their increased efficiency, such a convention as this at Milwaukee being an evidence of the thought and effort and money expended on the improvement of the official personnel. But if the unofficial personnel, which is no less a part of the Bureau's system, even if unrecognized by law, be overlooked, the very efficiency of the regular force will find itself hobbled and hampered in its endeavor to reach the public in whose interest the whole service is created. There is, therefore, to my mind, ample justification for any direct and instructive appeal to the newspapers through some special Government publication. But in lieu of any such issue there are certain practical reforms in the matter of the relation of the forecaster and the newspaper that are at the command of any observer in any station.

In the first place it must be remembered that by reason of the exigencies of newspaper service while the newspaper remains the same the reporters form a shifting medium as far as individuals go. What is done for one man one day has to be repeated for another man the next day; for too often the pressure of news, the balance of the office personnel, and other contingencies make it impossible for the most careful city editor, or news editor, or managing editor to assign the same man to write the "weather story" week in and week out. Many newspapers make an effort to develop special men, but the forecaster or observer who depends on the special "weather man" of any given newspaper will be apt to find that just when he most needs him a newcomer will be apt to appear in his place, the specialist having other duties to perform.

In the second place it is fatuous to take for granted either that the public or the newspaper can be fed on technical matter or matter stated in technical language. All that is suggested for newspaper publication should be lucidity itself, and as simple as the exact use of the ordinary vocabulary will allow. Any technical terms that are used should be carefully explained, and great care taken always to use the same terms in their exact scientific sense, particularly in cases where journalistic and public error have confused and confounded them. This primer-like simplicity of statement can not be too strongly insisted upon. Moreover, if lived up to, it serves the double function of teaching the observer to formulate his ideas in a clear and convincing manner, as well as illuminating the public through the work of a well-drilled reporter and a self-drilled forecast official.

In the third place, the forecast official or observer in any given station should not view the daily or occasional conference with reporters as in any sense an intrusion on the office routine, but as one of the most important functions his office discharges in its relation to the public. He should map out for himself a consistent scheme of weather and meteorological explanation; should prepare himself specially to be ready, on any given emergency in the way of a recurrence of familiar weather types that are repeatedly the object of public interest and newspaper discussion, to give an interesting account of just what the situation means, and what the causes are and what the effects will be.[a] This may seem formidable, and to call for more time than the forecaster has at his disposal; but if the matter is taken up progressively through the year the observer will find as he prepares himself on one phase of the weather after another that in twelve months he has run over practically all that is needed, and all he has to do in the future is to fall back on the material he has provided, with such incidental references to the weather of the day under discussion as differentiates it from its general type. As to details, I would suggest, for instance, that so simple a thing as the monthly summary (Form 1030), which usually arrives at most newspaper offices now a day late, on the 2d of the succeeding month, should be gotten out in time to be sent to the morning newspapers on the night of the last of the month, that its bald table of fact should be prefaced by a running account of the peculiarities of the month as compared with other months, all written in as free and as interesting a way as the observer can command. Of course, the preface should not be left until the last hours of the last day, but should be prepared at leisure, notes being made as the month goes on, and should be ready in the afternoon of the last day, only needing the final data to release it. Prof. A. J. Henry, of the Washington office, has made the very practical suggestion that the monthly summary (Form 1030) and the monthly table of averages (Form 1079) be issued together. If this be done, the running account can be made to combine a survey of the past month with a forecast of possibilities, as it were, in a way that can not but be entertaining, and it goes without saying that newspapers that shy at the bald, uninviting table will print such a monthly article with avidity. As it is, many newspapers often try to write a general article themselves, using the data received, and do it rather haltingly, so that there is a chance here for an observer to make himself personally felt in an important particular of his work.

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[a] An example of high-class effort in this direction was the issuance by the Chicago office, under the direction of Professor Cox and the special service of Mr. Walz, of a luminous account of hot waves and high temperatures prepared for printing after the close of the hot-wave period for June–July of this year (1901).

But, aside from so regular a thing as the monthly summary, there is the eternal question of the hot and cold waves, the thunderstorm, the mild spells, the droughts, wet weather, explanations of which phenomena the newspaper is continually reaching out for. If in its efforts to obtain explanations of these phenomena the newspaper is given the dreariest routine information by the observer, the disposition is to treat the matter in a sensational, or, as it is called in newspaper offices, in an "interesting manner," in sheer self-defense. Here is, indeed, the forecast official's opportunity. Let him prepare himself, in writing, to give the essential facts as to causation as it is revealed in the Weather Bureau brochures on all the phenomena he is called on to discuss with reporters. The matter should take the form of a concise statement that is not too dry, even if scientifically accurate. Let him prepare these articles, written, as the year develops, on one phase of the weather and another from January to January. They should be typewritten, so as to be easily duplicated as often as wanted. Then when a hurricane is approaching, or a given region is tornado struck, let him give to the reporters these summaries of the facts as to the causation in issue of the tropical cyclones or in the formation of violent local rotary storms, explaining by reference to the daily map the precise situation that exists on the particular date in question and the specific relation of the given actual phenomena to that that has occurred before. If this be done for all the important phases of weather that visit any given locality; if the observer always has his material handy for comparisons of, let us say, the heaviest rainfalls, the longest droughts, the highest hot-wave maxima, the percentage of inaccuracy, and the foolish, bewildered muddlement that is too common a feature of newspaper accounts of weather phenomena to-day will be reduced to a minimum.

It will probably occur to many that the so-called "means" book, planned by Professor Henry, and now a matter of office routine, to a certain extent affords a record that could be utilized for the purposes herein noted. This is true, but my concern is that the forecaster keep this informatory reference matter not as an official record, but merely as a personal convenience in the issue of his relation to the newspapers. Hence his collection of material can take on a freer form, and, in addition to books and Government reports as a nucleus, I would suggest the use of large envelopes, classified under general titles according to the Dewey, or any other system, which envelopes may be filled with matter from any source bearing on the subject called for, and which envelopes will form an easily get-at-able scrapbook collection, constantly increasing in volume as time flies and additions are made to the collection. The writer has found that stout manila envelopes, 10½ inches by 7 inches (which are large enough to hold the Government bulletins and monographs), indexed on their flaps, afford the most convenient method of classifying and keeping weather data. They take up little space, are easily handled, and a well-filled envelope under any given head, such as "thunderstorms" or "hurricanes," represents a maximum of detailed information with a minimum of inconvenience as to its immediate availability. The pasted scrapbook is a wasteful, unsystematic method of collecting or keeping data, and is particularly objectionable when it comes to the question of turning over any given data to a newspaper for special use. At first the available data may seem incomplete to the local station man, observer, or forecast official, and as for his own précis or abstractions of special articles, or summaries of comparative research along a given line, they may seem to him at first very unsatisfactory. Indeed, it may not be, will not be, easy for the observer at first to write special articles just as he would like to see them, but facility will come with trial and experience, and one year's effort will revolutionize his relation to reporters—and this means to the community—and he will thus not only increase his personal usefulness to the Bureau, but will enhance its value greatly in the eyes of the public.

It should also be remembered that in preparing articles to cover specific weather occurrences many an article can be made to tell in signal style if it be accompanied by a carefully prepared map. And in this matter of map making, I wish to say that just as the public and the newspaper are unprepared to-day for the undiluted technical weather article, so are they unprepared to understand the daily weather map unless it be simplified on publication and be accompanied with the most lucid explanation. The regular daily weather map itself reduced in size, if reproduced with all its data in the newspaper, is a Chinese puzzle, and of doubtful value, since its complications are meaningless to the average reader, and not being understood, rather repel him, and the map signally fails in its purpose. As a piece of routine, I am not in favor of the daily use of the map in the newspapers, but I am a firm believer in the use of a special map on occasions when the public mind is ready for it, owing to the special interest in some phase of the weather, when the map can be made to tell the story of weather causation in a striking and positive manner in a way that gives what words can not convey, and is a direct reenforcement of the text.[a] Such a map requires, however, the active cooperation of the forecaster in its preparation, and he must be quick to see what feature shall be accentuated in order to reach the general reader and teach him a needed lesson in meteorology, as well as be within the grasp of the newspaper men themselves. But even such a map loses most of its value unless the explanation that accompanies it really explains, and is written from the point of view of one who realizes what the public does not know, but should know. Printed anyhow, merely for the sake of printing a map, the result is pointless, and advances neither the interests of the Bureau nor dynamic meteorology one whit; but rightly used the occasional map can accomplish an important work. It allows an important weather fact to be driven home, as it were, and affords a unique chance for special studies in weather contrast to be made; and when presented at the right psychological moment, so far as the public is concerned, has a high educational value. What is more, the newspapers will use maps whenever they see there are pith and point in them.

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[a] An idea of the kinds of maps that are most effective in newspapers is given in the selected group of weather maps which originally appeared in the Philadelphia Press, and are reproduced as to map and text as an appendix to this article.

But aside from the amplification of the daily forecast, the writing of occasional articles, and the preparation of occasional maps, a good stroke for meteorology and the Bureau can be made by calling attention to special articles in the Monthly Weather Review, which, if they are too long for reproduction in full in the newspapers, might be conveniently summarized or abstracted; for, although the Monthly Weather Review is an excellent publication for a newspaper to have on its exchange list, at present only a few newspapers make use of it, and yet that its articles are appreciated is evidenced by the way in which some one article copied into a leading newspaper will make the circuit of practically every important newspaper in the country.

This may seem to pile up the agony of work on the forecaster above all endurance, but in a given year my suggestion might only call for him to work out a dozen explanations, to suggest the use of half a dozen maps, and to rewrite one or two articles from the Monthly Weather Review. In view of the enormous importance of the better relations that I am sure could be established with the newspapers and the public by doing these things, the game, I think, is worth the candle. And, in conclusion, I do not want to be understood as believing there is serious shortcoming in the work of the local forecasters or the station men in general. On the contrary, of the two factors that play their part in presenting weather data to the public, the forecast officials, observers, and the newspapers, it is the forecast officials and observers who are a monument of painstaking patience under irritating and trying conditions, and it is the newspapers that too often fail in their duty, and in so failing make it so very difficult for the forecasters, observers, and Bureau employees generally, be they never so earnest or devoted, to straighten the matter out and make headway in the instruction and illumination of the public. There is, I hope, a turn in the tide; the new generation receiving a better education in physical facts will revolt at obscurantism, the newspapers will have to take a new tack; but I am convinced that the Bureau itself in a few years could work a complete about face if definite attention were given to the improvement of its relations with the newspapers and to the illumination of the average newspaper office along the lines here suggested.

APPENDIX TO "THE FORECASTER AND THE NEWSPAPER."

As an example of what can be done to drive home a specific lesson in causation, and also in order to illustrate the pointed occasional use of weather maps, simplified for newspaper publication, half a dozen examples of maps that have appeared in the columns of the Philadelphia Press are inserted. These maps are not especially picked maps, but represent the kind of map the Press prints when there is some occasion for using a map. It has been my method on the Press to utilize any given incident in the way of acute storm phenomena, or special climatic effect, or any incident in the news of general interest, such as the international yacht races, election day, etc., as an occasion for using a map if the meteorological conditions are clean-cut and are really significant. These maps are always very much simplified and vary from time to time in the matter of the particular meteorological feature that is accentuated, the one object being, however, first, last, and all the time, to make the subject as clear as crystal to the average reader.

Exhibit No. 1 was published on June 30, 1901, and represents in its simplest form the mechanism of a hot-wave circulation for the Central and Middle States and New England. There are occasions when a larger section of the United States must be included to make the conditions clear, but as a rule the smaller the section reproduced the better, the entire map of the United States only being reproduced when it can not be avoided. As will be noticed in this case, the idea is to give the readers a lesson in hot-wave causation. This lesson of June 30 was followed by a more definite example of how hot waves are caused, by the reproduction on July 2, 1901, of the weather map of July 1 about the time that the hot wave in the Eastern States had reached its maximum. This map is shown in Exhibit No. 2 as it was republished eleven days later in conjunction with the cool-weather map of July 12, 1901, to set out one of the most beautiful contrasts in weather causation which it is possible to see in summer in the Eastern or Atlantic Coast States. As must be clear to the dullest, on the map published on June 30, and on the map of July 1, republished on July 13, there is a south-to-north circulation from the subtropics, from out the barometric high pressure (anticyclone) into the barometric low pressure (cyclone) to the north. So long as these respective aerial eddies or barometric pressures maintained the relation shown on these maps the hot wave persisted, but the reversal which set in on July 11, and is specifically revealed on the map of July 12, published July 13, gives a marked circulation from the subpolar anticyclone (high pressure) over the lakes into the subtropical cyclone (low pressure) off Hatteras, with a consequent north-to-south circulation of the winds and cool weather for New England, the Middle States, and the Atlantic littoral as far south as Georgia. The hot-wave mechanism in the Mississippi Valley, it is true, remained unchanged, as a high pressure over Texas kept up a south-to-north circulation in a low-pressure area in the Northwest over the heated interior, and did this for more than a fortnight longer. But the map the Press used was only intended to explain the movement and the weather within the vicinage of the Middle States, and all other features were ignored.

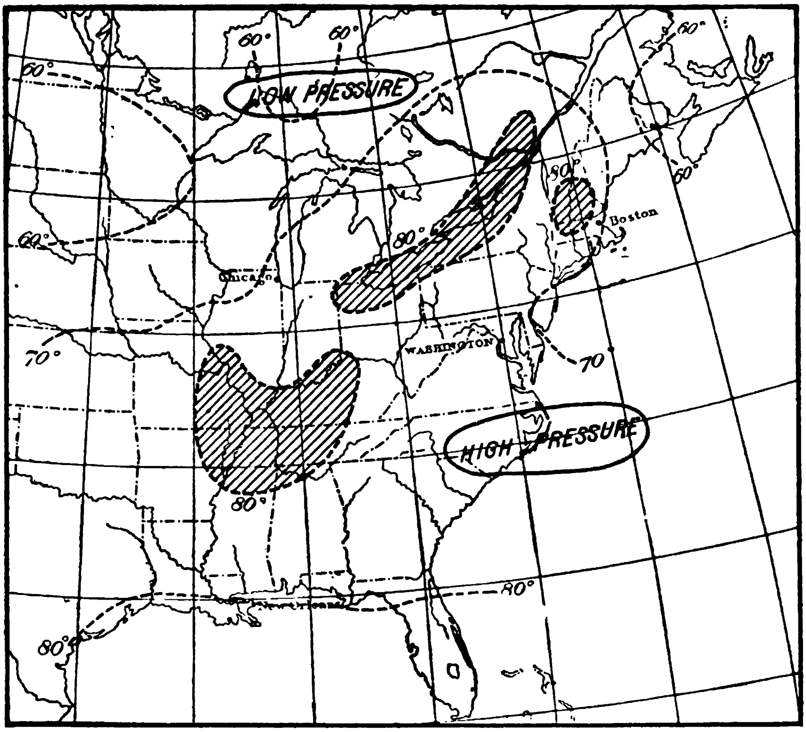
In Exhibit No. 3 an example is given of how to use the weekly crop report map. Here only the maximum temperature areas are reproduced, but as these mapped out the region of the greatest devastation to the crops, the map had a special significance, and the confusion of lines, which of necessity marks the official map with its minimum as well as maximum lines, was avoided. In the winter time, after the rule of a cold wave, a map of minimum lines is most instructive and timely. Again, whenever the opportunity arises for accentuating the difference between the general cyclone and the local violent outbursts, squalls, thunderstorms, tornadoes, etc., it is worth while doing, since no terms are more confused than the exact use of cyclone and tornado. No one, of course, who ever looked at the weather map of the United States of March 27, 1890, and saw how the general continental cyclone covered with its wind circulation two-thirds of the United States, reaching from the Atlantic to the Rockies, from the Gulf to Lake Superior, could ever again confuse it with the tornadoes which it set up in Tennessee, Kentucky, and Indiana, since even if the latter outbursts were represented by dots they (the dots) were too large in relative size in comparison with the great general storm movement as revealed on the map. To show that, though destructive, local outbursts are short lived and insignificant local eddies, a map such as Exhibit No. 4 is useful, as it serves to beat home the facts as to the relation between a general cyclonic circulation and local phenomena, just as Exhibit No. 5, the map showing the Galveston hurricane (tropical cyclone), which was printed on the morning of Sunday, September 9, having been drawn and printed hours before the news of the great disaster was sent over the country, plays an equally important part in fixing the average reader's ideas as to the relation of the rotary circulation of winds in a cyclone and its translatory movement along its path as an eddy of enormous magnitude.

The movements of great general cyclones are always very instructive, and nearly every year there is some particularly marked case of one perfect in its typical circulation and weather covering a large part of the country with its storm phenomena that is worth reproducing, just as the occasional perfect anticyclone in the early fall, winter, or early spring makes an excellent exhibit of the effects of the opposite or clear-weather type of eddy. While the anticyclones of November 5, 1900, were not such perfect types of circular eddies as are sometimes seen, still it has been the wont of the Press, whenever the weather preceding election day is marked in character, to print an informatory map and so aid in making the daily forecast and probabilities of election clear. Exhibit No. 6 was published on Tuesday, November 6, 1900, the day of the Presidential election. It was headed, for picturesque purposes, "Republican Weather To Rule," but maps and lines were intended to convey a lesson in meteorological causation and weather drift, and, as will be remembered, the "clear weather" forecast was justified by the halcyonic conditions that prevailed the country over.

These six maps here republished can easily be improved upon, and all that is claimed for them is that they were published from no aimless desire "to have a map," but with a definite, equipped purpose in view each time. As reproducing or redrawing the regular daily United States Weather Bureau map and selecting the special features calls for special effort, it might be wise for the Government to issue a black and white map in outline, upon which any features from the daily map could be traced by the local officials with ease, which maps could then be reproduced by the newspapers without redrawing. The present daily weather map, which is about 10 by 7 inches, is too faint in color and too small in proportion for use directly. In general, it may be said that all the green, blue, and brown inks used in Government maps are unsuitable for direct reproduction. The situation calls for a map of the United States with black lines on a white ground, at least 12 inches across from California to Nova Scotia, and 9 inches from Canada north of Lake Superior to the Gulf at Havana. Such a map in blank, if accessible at every station, would simplify the problem very materially, both for the newspaper and the local forecast official. As the question of space, as well as meaning, is ever a pressing one in newspaper offices, it is worth noting that Exhibits 1, 4, and 5 are facsimiles of "two-column cuts," which size the Press has found meets the map needs in most cases, while Exhibits 2, 3, and 6 are reductions of "three-column cuts." But, after all, in addition to the map, one must have definite ideas and a method in reproduction, and above all a letterpress with each map that tells what it is there for in a way to catch and interest the casual reader.

EXHIBIT NO. 1.—*The blanket of summer heat.*

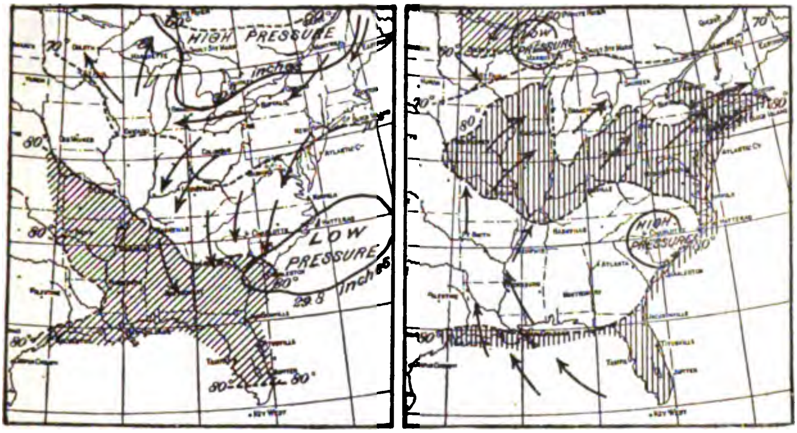
[From the Philadelphia Press, June 30, 1901.]



The weather conditions prevailing at 8 a. m. yesterday, as shown on the United States weather map, were very similar to those that set in early in the week. They were the familiar conditions peculiar to a hot wave and offered slight prospect of a radical or immediate change. These conditions were in the nature of an area of high barometric pressure over the Southern States and a low pressure over the lakes. This caused a sluggish circulation of wind from the South to the North and was responsible for the general hot wave with its various pockets of overheated areas, the temperatures prevalent at 8 a. m. on the map representing areas that later in the day gave maximum temperatures from 15° to 20° higher.

EXHIBIT NO. 2.—*Contrasts in July weather.*

[From the Philadelphia Press, July 13, 1901.]



(Weather conditions, 8 a. m., July 12.) (Weather conditions, 8 a. m., July 1.)

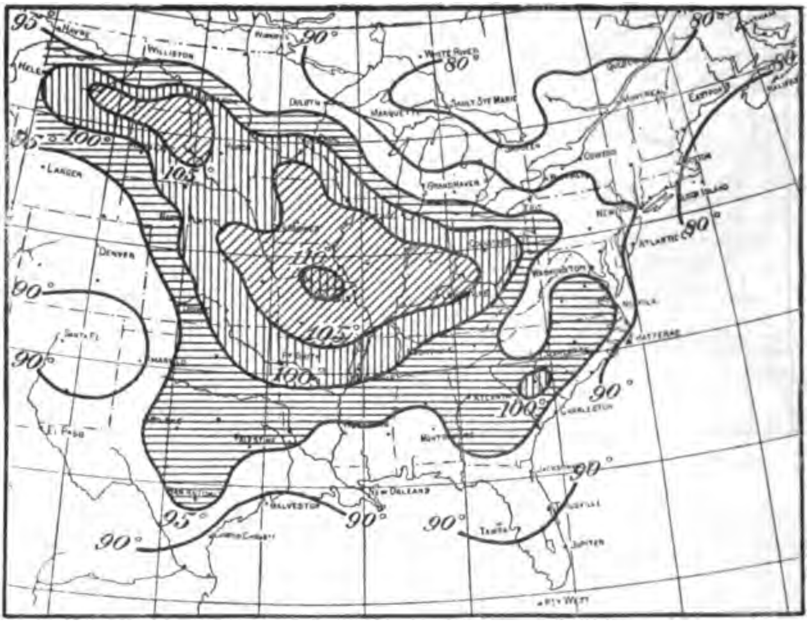
The cool weather of yesterday, as the 8 a. m. map of the United States Weather Bureau makes clear at a glance, was due to a north to south (northeast to southwest) circulation from out an area of high pressure (barometric) over the lakes into an area of low pressure off the Carolinas. Not only the weather but the circulation was thus in absolute contrast to that which prevailed on July 1, which represented the typical hot-weather state of things, the winds, as the second map shows, moving from the tropical South to the North from a high-pressure area over the Carolinas to a low pressure over the lakes. So long as the high pressure remained to the south of the Mid-Atlantic and Central States the hot wave of last week continued in force.

The first break in this hot-weather type of circulation occurred on Sunday, and since that time the pressures over the South Atlantic coast have been relatively low. Yesterday, however, revealed the most definite change from the hot-weather conditions of a week ago, and in consequence the New England States, the Middle States, and the northern tier of Southern States enjoyed what was a cool circulation from the north and from the oceans, and the tropical circulation was beaten back toward the south and southwest. The most decided effects of this cool-weather circulation were, however, confined to the Eastern States, the hot wave in the Mississippi Valley and the extreme South being little affected.

As the region shaded in yesterday's map shows, the 80-degree line at 8 a. m. ran up as far as Missouri. This meant high temperatures of 100 or so later in the day, as there could be no let-up in the Mississippi Valley hot wave, since it was controlled by a circulation moving from the South into a low-pressure area over the extreme Northwest (not shown in the map), and was too far away to be modified by the north to south circulation that prevailed over the Eastern States from Michigan to Maine and from Canada to the Carolinas. As the winds blow in and about the low-pressure area in cyclonic fashion, and as the area itself moved to the northeast, the coast and coastal States experienced a typical ocean storm, with rain, on-shore winds, and a high surf.

EXHIBIT No. 3.

[From the Philadelphia Press, August 1, 1901.]



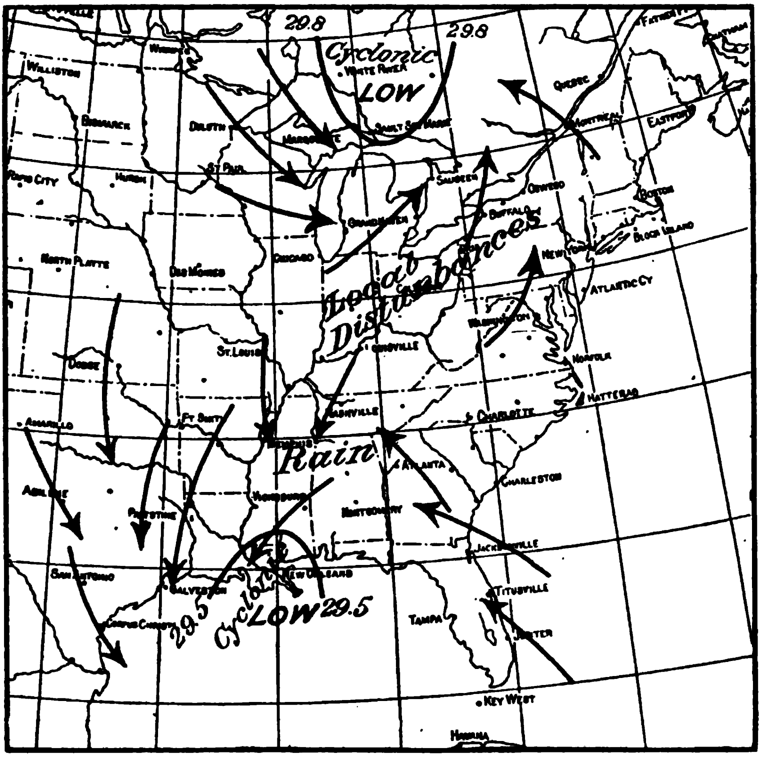
With the great drought in the corn belt of the middle Mississippi and Missouri Valley States broken, apparently for good, the weekly map of the climate and crop division of the United States Weather Bureau, showing the conditions that prevailed during the culminating week of the drought, July 22-29, possesses special interest. The map, reproduced in the Press to-day, shows the extent and location of the regions of maximum temperatures for the week in question. These lines of highest temperature map out very accurately the sections where the drought was the severest, the line of 105° F. covering very nearly the corn-growing region, with Columbia, Mo., centering an area, with a diameter of 100 miles or so, where the temperatures reached the 110° level for the maximum and never went below 70° for the minimum. In this pocket of overheated territory the minima were often above what would be the normal maxima for July, and on some days the mean temperatures were over 95°.

Moreover, although this map only represents the conditions for the last week of the drought, there was so little material change in the reign of the hot wave over the Mississippi-Missouri Valley States for the month that it gives a fair idea of what these sun-baked regions experienced for thirty-one days. The first week in July saw the region about Columbia, Mo., for instance, with maxima of 105°, while the 100° line covered the main corn belt, with an isolated patch of 100° lying over the coastal region of the Middle States, Philadelphia's maximum being 103°. After that week cooler weather prevailed generally in the East, and though the week ending July 15 saw an enormous extension of the 100° line in the Mississippi Valley and the Gulf States, with Columbia, Mo., the center of the 110° patch, the Eastern and Middle States escaped the worst. There was no let-up in the West, however, and the map for the week ending July 22 saw the line of 105° covering a large part of Missouri and Illinois and small sections of Nebraska, Iowa, and Wisconsin, while the 100° line for the week ending July 22 covered almost all of South Dakota, Wisconsin, Nebraska, Kansas, Oklahoma, Arkansas, Missouri, Illinois, Indiana, Ohio, Kentucky, and Tennessee. The area is very nearly the same in extent as the 100° line of the week ending on Monday, as is shown by the map. Of the average yield of 2,100,000,000 bushels of corn grown in the United States, about 800,000,000 bushels are grown in the area covered by the 105° line in the map, with Columbia, Mo., as the center, and it was in the area thus mapped out that the heat for the month of July was the most severe and unintermittent and the rainfall the least.

gav. maxi.

EXHIBIT NO. 4—*The rule of cyclonic weather.*

[From the Philadelphia Press, August 16, 1901.]



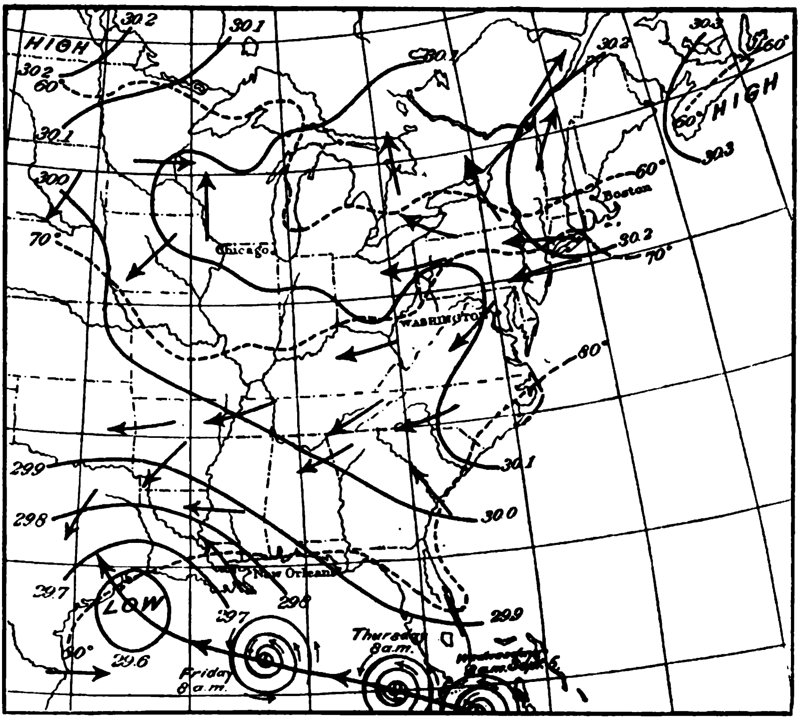
The United States Weather Bureau map representing conditions at 8 a. m. yesterday revealed the eastern half of the United States controlled as to its weather by two areas of low barometer, which, according to invariable law, are the seat of a cyclonic circulation. The low area, or general cyclone, over the lakes in its passage eastward was marked by the formation of local disturbances, thunderstorms, squalls, and small tornadic outbursts, one of which, accompanied by an extensive thunderstorm, passed over southern Philadelphia and Camden. These disturbances usually occur in the southeast-to-south quadrant of the general cyclone, from 300 to 600 miles from its center. Consequently, yesterday local storms were set up in the morning in Indiana, Ohio, and Michigan, and as the center of the general cyclone moved eastward toward evening it was in a favorable position to superinduce local disturbance in southern and eastern Pennsylvania and the vicinity of Philadelphia.

The lake cyclone confined its influence to the upper half of the country east of the Mississippi Valley, while the Gulf coast and Gulf States were under the influence of the Gulf cyclone, whose center has been nearly stationary for three days, in consequence of which its winds have raised some high tides in the Gulf, and, judging from the latest reports, the losses to property in New Orleans and Mobile by flood may be followed by loss of life on the low-lying islands of the Louisiana and Alabama coast. These islands are but little above the ordinary high water, and many of them are used as summer resorts. While the winds and cyclonic tides have done the worst damage along the coast, the heavy cyclonic rains have done some damage in the interior, although up to last night the storm had shown slight inclination to move inland.

Both cyclones show the peculiar inward circulation of the winds about the center, and reveal their great area, as compared with the small but violent local disturbances which the northern one set up on its southern edge, and which, if indicated on the map, could only be represented by a dot.

EXHIBIT No. 5.—*The track of the hurricane.*

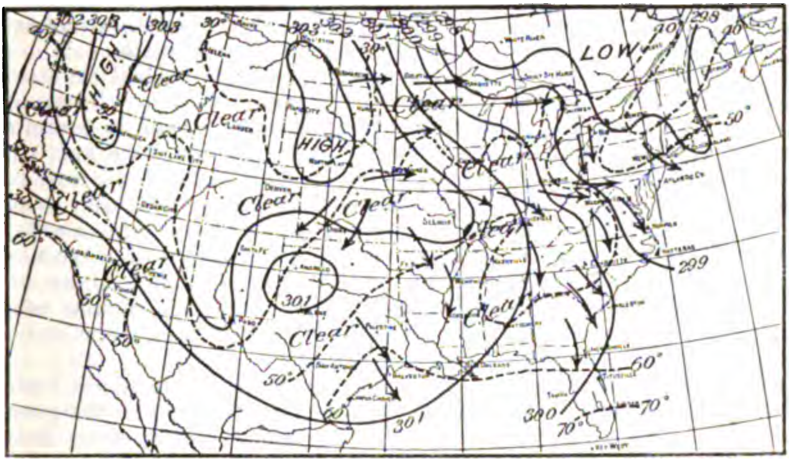
[From the Philadelphia Press, September 9, 1900.]



The path of the average tropical hurricane, while seemingly subject to amazing vagaries, really varies very little. Those that move over the West Indies, near or north of Porto Rico in August, recurve in the Bahamas and, turning northeast, move up the coast often parallel, but little by little turning to the east and "going out to sea." Those that recurve over or just west of Florida follow the coast line more nearly and are very apt to take in every town from Pensacola and Jacksonville to Boston and Portland, Me., and give them a taste of heavy rains and high winds. The September cyclones usually recurve near Florida. The United States Weather Bureau map of 8 a. m. yesterday indicates the cyclone (shown by the area of low barometer) just moving inland from the Gulf. Its high winds and high tides, due to the winds, seem to have done considerable damage on the low-lying Louisiana coast line. As the storm advances inland it often loses all its energy, and its track, which then tends northeast and may carry it up the Ohio and St. Lawrence valleys, is made manifest only in excessive rains, but not in gales or dangerous tempests. As the map makes plain, Philadelphia and vicinity was not affected by the cyclonic winds, but by an easterly and northeasterly circulation moving out of an area of high barometer (anticyclone) over New England. This type of circulation gives a damp, but practically stormless nor'easter, often without rain at all, and with very light winds. It is only when the northeast wind is flowing into and about a low barometer (cyclonic) that it means a gale.

EXHIBIT NO. 6.

[From the Philadelphia Press, November 6, 1900.]



This map of the United States represents the weather conditions as reported by the United States Weather Bureau at 8 o'clock yesterday morning. Since the weather drift in the United States is from west to east, conditions that are prevalent on the Rocky Mountain slope one day repeat themselves farther eastward the next day, and the weather of the Mississippi Valley tends to duplicate itself over the Central and Middle States within twenty-four hours. The "highs" and "lows" on this map refer to barometric pressures, not to temperatures, the solid lines inclosing regions of the same barometric pressure, while the dotted lines connect the points that have the same temperatures. The "high" areas are the seat of pressures above the normal of 30 inches and are in consequence a center of dispersion for the winds, which move down and out from a "high" spirally in all directions. This descent of dry and relatively cool air makes the "high" the center of clear-weather phenomena, while the "low" area, where the winds concentrate and ascend, is the center of stormy weather. On the map yesterday two separate "high" areas, one east and one west of the Rockies, gave over three-fourths of the United States clear weather. The eastern "high," which was central over the Dakotas and Nebraska, conditioned the winds and clear weather all the way to the Atlantic coast. As both "highs" will drift east to-day, they promise to continue fine weather from the Pacific to the Atlantic, as the "low" area, with its clouds central over northeastern New England yesterday, will have passed east to Newfoundland, and in its place a very steady high pressure, true American weather, should cover the entire length and breadth of the United States. The temperatures promise to be moderate and the winds light.

VALUE OF THE CLIMATE AND CROP AND STORM WARNING SERVICES OF THE WEATHER BUREAU TO THE INDUSTRIES OF CUBA AND OTHER ISLANDS OF THE WEST INDIES.

By Mr. M. W. HAYES, *Havana, Cuba.*

The United States Weather Bureau maintains a complete chain of observatories from Port of Spain, Trinidad, to Havana, Cuba. During the hurricane season daily 8 a. m. observations are telegraphed from all of the West Indian stations to Havana, the headquarters of the West Indian forecast district, and certain morning reports are received from the United States. All these reports are charted immediately, and a study of the existing conditions made.

As a rule no public forecast is made unless disturbed or stormy conditions exist. Should the charted reports indicate threatening weather, but show no marked storm, this information is communicated to the marine interests. Storm or hurricane warnings, when such warnings are demanded by the charted conditions, are telegraphed immediately to the islands likely to be affected, and to such other localities as the marine and other interests render advisable.

The method adopted for the systematic distribution of warnings is to divide the West Indies into specific sections, and make each Weather Bureau station, and also the United States consular offices at St. Pierre, Guadaloupe, St. Thomas, and Port-au-Prince, subdistributing points for its particular section.

Telegraphic facilities are fairly good throughout the West Indies. To every island that it is possible to reach by wire, when threatened by a hurricane, there is telegraphed by one of the subdistributing points a plainly worded warning of danger.

Sometimes it is preferable to take even more active steps than the display of flags to disseminate information of a very urgent nature; and, again, frequently the information is intended solely for the benefit of vessels ready to leave port and need not be communicated to the general public (as it might cause unnecessary alarm); hence each subdistributor has a carefully conceived plan for the handling of the various kinds of information sent to him. The general method followed is for the subdistributor to advise marine interests, Government officials, and repeat the message to all United States consular or other officials in his section, and these officials in turn give it the publicity the circumstances may demand. When a hurricane is predicted a special effort is made to display the signal on flagstaffs which can be seen by passing vessels, enabling them to seek timely shelter.

On nearly all the islands the Government officers, on the receipt of an emergency warning, take active measures to give the information as wide circulation as possible. In order to accomplish this end, use is made of the telegraph and the telephone; also mounted messengers are sent out, and signals are made by firing cannons and rockets.

When one considers that the largest number of the inhabitants of the West Indies live in houses that are none too stable, also the innumerable small sailing vessels engaged in interinsular trading, fishing, and sponging, and the many large sailing vessels and steamships plying between the Antilles and the other ports of the civilized world, one appreciates the value to these interests of judicious warnings. Such warnings enable the inhabitants to take all possible precautions to reduce the loss of life and the damage to property to a minimum, and the vessels, possible to reach, to seek a safe anchorage. The attitude of the executives and other high officials of the various islands is an evidence of the esteem in which the forecasts are held and the confidence placed in them. These officers make energetic efforts to have warnings spread throughout their jurisdiction, and especially to have them reach isolated points, exposed rural communities, where many lives are at stake, and ports where the small sailing vessels frequently enter.

The Weather Bureau warnings have held in port the large passenger steamers plying to and from the West Indies, as well as the pleasure yachts, and the small interinsular sailing vessels. It is indeed a pronounced recognition of the value of our warnings to have vessel masters that have been sailing in tropical waters for long years, and who naturally have a rather high opinion of their knowledge of the storms of that region, to remain quietly at anchor, despite their desire to sail, so long as they are advised that they would incur the risk of encountering a hurricane.

While the value of the service to the islands of the West Indies is great, it is all incidental, in a way, when we consider the benefits of this branch of the weather service to us at home.

By having the West Indies observatories, the Weather Bureau can watch the hurricanes from their inception or appearance, and by following the storms as they move through the West Indian region and issuing advices in regard thereto, the public and shipping in the United States likely to be affected by hurricanes are not subjected to the great financial losses common in the days before the establishment of this particular service of the Bureau.

The Cuban section of the climate and crop service of the Weather Bureau was organized in the early part of 1899. Previously no successful governmental or other systematic effort had been made to locate meteorologic outfits throughout the island. Observations, however, have been made with more or less regularity at scattered points in Cuba.

The most important industry of the island is agriculture. As the intimate relations between climate and agriculture are universally recognized, it is not surprising that those who volunteered to make observations when the United States Weather Bureau offered to place instruments at selected and well-distributed points belonged to Cuba's educated class. I think I am justified in saying that no climate and crop section of the Weather Bureau has a corps of voluntary observers of a higher degree of excellency than has the Cuban section.

At present, observations are made at 39 points, uniformly distributed over the island. The meteorological observations, together with a summary of the observers' remarks on matters relative to climate and crops, are published monthly in English and Spanish. Every Tuesday there is published, in English and Spanish, a weekly bulletin on the condition of the crops as affected by the weather. The matter upon which this bulletin is based is furnished by a large corps of voluntary reporters, composed of planters and others directly interested in the subject. These reports are forwarded by mail or by telegraph.

The prestige now enjoyed by these publications is gratifying. Lengthy extracts are published by the newspapers, and a large mailing list is required to meet the demand for the reports made by the Cuban public and by interested persons in the United States.

The Cuban planter, on account of the genial climate and the wonderful fertility of the soil, is generally enabled to raise exceedingly profitable crops. He is ever on the alert to make every possible improvement, and he fully appreciates the necessity of reliable climatic data in connection with agricultural operations. To him authentic temperature and rainfall data, linked with reliable and intelligible notes on crop progress and conditions, are invaluable.

The climate and crop reports are also used extensively in the efforts being made to further develop the island. Naturally the first information sought by homeseekers or those contemplating the placing of capital in Cuba is about its climate. The voluntary observing stations of the Weather Bureau so thoroughly cover the island that they give a most comprehensive knowledge of the weather that prevails at any given point.

The two crops one always associates with agricultural Cuba are sugar cane and tobacco. However, numerous other crops are raised, and still greater diversification is possible. Steps are already being taken in that direction, and to them climatic data are important from their beginning to their termination.

VALUE OF THE CLIMATE AND CROP AND STORM-WARNING SERVICES OF THE WEATHER BUREAU TO THE INDUSTRIES OF PORTO RICO.

By Mr. G. Harold Noyes, A. B., *Boston, late of San Juan, P. R.*

In considering what the benefits of the climate and crop and storm-warning services of the Weather Bureau may be to the industries of Porto Rico, it may be well to note the type of weather that obtains there.

Porto Rico is 18° north latitude and 66° west longitude, and is surrounded by a warm, deep ocean. One of the greatest ocean depths lies just north of Porto Rico, where the soundings show a depth of some 5 miles of water.

The temperature of the ocean surface water near the shore of Porto Rico is about 78° F. This maintains a controlling influence over the mean temperature of the lowland near the shore. The mean annual temperature of San Juan is 78°. The strong easterly trade winds carry the ocean temperature over the island. The island, being very small, does not develop atmospheric conditions of its own. The temperature of the island is practically constant, there being a difference of but 8° between the highest and the lowest monthly means.

Precipitation is very variable—excessive and frequent or light and occasional. Heavy, quick showers will fall from an almost clear sky, and again the most frowning clouds will give no rain. The rainfall varies from 140 inches on the windward shore of the island to 50 inches in well-sheltered leeward districts.

These figures exemplify in one way the value of the climate and crop service. Our voluntary observers have enabled us to find out what the climate of Porto Rico is. Prior to the establishment of our service some few persons took observations, but when the section director sent out a circular letter requesting copies of any weather records that might have been kept he was answered by the one man that replied to the circular, "that meteorological accounts could not be expected from people that did not keep even an expense account." Interested Americans and Englishmen began to ask about the rainfall of different parts of the island; engineers and sugar men, especially, desired to know the averages and extremes of precipitation. Some sugar planters prefer a dry locality and eke out the proper amount of moisture by irrigation; others consider a wet locality better, and trust to good fortune not to have their plantations washed away by a deluge. Some few hotel men have sought information as to temperature, but they are usually disappointed. It is perhaps unfortunate that the mean daylight temperature for the whole year is above 80°, and this with a relentless sun and humid wind.

It is difficult to estimate the value of the climate and crop monthly and weekly reports to Porto Rican interests. There is no such thing as competition; the condition of one man's crops does not at all disturb another who raises the same product. Americans that control large estates value the reports for their representative character and accuracy. The greater part of the masses, it must be confessed, pay no attention whatever to the reports. They can't read. They perform all the labors incident to farming with a machete. They are not educated up to the fact that the reports are of value, and they will not be for some generations yet to come. We must consider that we in the United States raise crops in the most modern fashion possible, and take advantage of the climate and crop reports as being necessary to the best interests of agriculture. But in Porto Rico methods are primitive; crops are put in and if they fail from lack of attention, such as being choked by weeds, or washed out by torrential rains from want of proper ditching, the planters shrug their shoulders and complain of fate. So we see how difficult it is to ascertain how much value the climate and crop service is to the large number of the islanders at least.

The newspapers publish extracts from our reports with frequent *irregularity*, and never give proper credit to their source until very urgently requested to do so.

The storm-warning service in Porto Rico keeps the marine interests informed as to unsettled or threatening weather in the zone of tropical cyclonic development. At times the post, telegraph, telephone, horseback rider, and runner are used to warn everyone that it may be possible to reach of the approach of a hurricane. It is thankfully to be said that the hurricane signal does not have to be often displayed; but when it is the effect is a stampede. Buildings are tied down to the ground, doors and windows barred, and, indeed, every precaution is taken to forestall as far as possible the fearful consequences of a catastrophe, the fatalities of which are all too well known. Vessels seek cover in some deep but sheltered harbor, and even then may be wrecked with all anchors down and full steam up. The value of the storm warning in Porto Rico is unquestionably great.

When the hurricane signal was hoisted in the island the first and, thus far, the only time there was some scoffing by native "amateur meteorologists:" for, "How could Americans know anything about tropical hurricanes, having been here such a short time?" But the warning was so timely and the justification so absolute, that now almost any American red flag will have the effect of the *bona fide* hurricane signal. When the usual red flags are hoisted over the military rifle range for target practice the telephone rings, and terror-stricken inquiries are made as to the (supposed) approaching cyclone.

Unsettled conditions that are liable or likely to develop into definite storm centers are reported at once to persons at every port having marine interests at stake. Thus vessels are kept in port instead of being caught at sea in a storm. It is to be much regretted that the power of a tropical hurricane is so great that its destructiveness will ever be enormous. Tropical vegetation is of such delicate and weak structure that a wind of but little more than ordinary force will cause great destruction. Houses are not made with any degree of strength in tropical climates, so that any of the storms of the intensity such as recur week after week in temperate latitudes during winter would level them to the ground. Our hope is to have the people so prepared that they can protect themselves from the violence of the storm, and being forewarned not suffer so much as would be the case were there no storm warning issued. Marine interests are the ones most helped by the warnings issued in Porto Rico. It is a matter of comforting assurance to a shipmaster to know that there is no disturbance threatening, or if there is, just where it is. So it is that the climate and crop service assists in the increase of agriculture, construction, etc. The storm-warning service guards against the sudden surprise of destruction.

The issue of a daily weather map during the hurricane season at San Juan, based upon observations taken at West Indian stations, would prove of undoubted value, especially in connection with the information message from the forecast center. Frequent inspection of voluntary and display stations is necessary, and the custom of the island requires that most formally polite courtesies and etiquette be maintained at all times. This end can best be had by having some resident native who is expert in Spanish and English as a permanent member of the service, either as clerk, observer, translator, or interpreter. This would to a large degree prevent the discontinuity of method when a change occurred in the incumbency of the office of section director. Every aid in administration of the service adds to its effectiveness, value, and prestige.

DISCUSSION.

Mr. J. L. CLINE. Some things regarding the climate and crop service of Porto Rico not mentioned by Mr. Noyes I think it may be of interest to call attention to. The island is only 40 miles wide and 100 miles long, and we have 38 voluntary climate and crop stations now in operation. In regard to publications, I will state that just prior to my departure arrangements were made with the Boletin Mercantil to publish the climate and crop bulletins in full, with headings as published in the official issue, and, besides, the synopsis will appear in the San Juan Daily News. The manager of the French railway, the only railway operating an independent telegraph line, arranged to distribute free all warnings received from Havana over his company's wires. He said, furthermore, that they were of so much value to him that he would not only distribute them free over his telegraph lines, but would instruct his employees to post them at the different stations along the railroad.

THE WESTWARD MOVEMENT OF THE DAILY BAROMETRIC WAVE.

By Mr. OLIVER L. FASSIG, Ph. D., *Baltimore, Md.*

The publication in the later volumes of the annual reports of the Chief of the Weather Bureau of the hourly values of barometric pressure at a large number of stations in the United States, in the West Indies, and along the north coast of South America affords an excellent opportunity for the study of the diurnal variations of the barometer over a wide area. Reliable hourly observations in the middle and higher latitudes of South America are still few in number. However, by selecting for study the month of July, during which the heat equator is thrown farthest to the north, this lack of data in the southern hemisphere is largely remedied. During this month there is a nearer approach to similarity in the distribution of land and water to the north and south of the heat equator; hence the conditions which largely influence temperature and pressure changes are more nearly comparable in the western hemisphere than they are over the eastern hemisphere, where the northern half is mostly land and the southern mostly water.

Until recently the question of the diurnal variations of the barometer has been studied mostly by means of the diurnal curve at isolated stations. In the present treatment of the subject the hourly values, or rather the hourly departures from the average for the day, at about 50 stations have been charted, after being reduced to a common hour, namely, seventy-fifth meridian time. In this way we obtain a view of actual conditions of pressure at the same instant of time over a wide area, similar to that of our daily simultaneous weather charts. Charting the observations in this manner brings to light some relations hitherto but vaguely recognized in the theoretical discussions of the subject.

In the accompanying charts (see plates X to XXXIII) I have plotted the departures from the average daily pressure for each hour of the day at stations in North and South America and in the West Indies, together with a few outlying stations. Lines were then drawn connecting stations having equal departures from the accepted normal value for the day, i. e., isoabnormals of pressure. The area covered by the observations extends from 0° to 140° longitude west of Greenwich; in latitude from 60° north to 40° south.

Taking up the charts in the order of time, the three most striking features within the area of observation are—

(*a*) The development and westward propagation of an area of pressure above the normal, an anticyclonic area, or perhaps it may more properly be referred to as a wave of increasing pressure, over the North and South American continents during the forenoon, followed by—

(*b*) The development and westward propagation of an area of pressure below the normal value, or a cyclonic area, during the afternoon, followed by—

(*c*) A period of comparatively uniform distribution of pressure during the night hours, which upon further study may be subdivided into two minor periods, namely, a secondary period of high pressure during the first half of the night, followed by a secondary period of low pressure during the second half of the night.

A closer study of the charts under consideration reveals the following characteristics of the primary and secondary anticyclonic and cyclonic systems:

(*a*) *The primary anticyclonic system.*—The area of pressure above the normal of the day appears upon the eastern coast of the United States between 5 a. m. and 6 a. m. It increases in extent and strength to 11 a. m. (seventy-fifth meridian), when it reaches a maximum, in July, of about +0.040inch over the United States, of about +0.020 inch over the Gulf of Mexico and the West Indies, and a maximum of +0.040 inch over the South American continent about an hour earlier. At the time of maximum development it extends from about 20° to 140° longitude west of Greenwich, and from about 70° north to 60° south latitude, the axis of the wave being in a NW.-SE. line through the center of the continental areas of the western hemisphere. The last traces of the area pass beyond the Pacific coast of the United

States about 4 p. m., the entire area passing a given meridian in about eight hours.

(*b*) *The primary cyclonic area.*—The primary area of low pressure immediately follows the primary area of high pressure. It appears upon the eastern coast of the United States about 1 p. m., attains a maximum development in the United States at 6 p. m. (seventy-fifth meridian), with a departure of −0.040 inch, and leaves the Pacific coast between 11 p. m. and midnight, the entire area passing a given meridian in about eight hours. Over South America it attains its greatest depth of about —0.060 inch at 5 p. m. (seventy-fifth meridian). In geographic extent, at the time of greatest development, the diameter measures about 8,000 miles, being equal in area to the anticyclonic system. The cyclonic development is greatest over the central continental areas.

(*c*) *The secondary anticyclone.*—The primary cyclonic area is followed during the first half of the night by a secondary area of high pressure, feebly developed over the North American continent during July, but quite well marked over the colder southern continent. Its greatest development is attained between 10 p. m. and 11 p. m. (seventy-fifth meridian), when it covers the entire South American continent and adjacent portions of the Atlantic and Pacific oceans and the eastern portion of the United States. The maximum departure is about +0.030 inch. In geographic extent it has about one-half the area of the primary cyclone or anticyclone.

(*d*) *The secondary cyclone.*—The secondary area of high pressure is followed by a secondary area of low pressure. This is equal in geographic extent and in the degree of its development to the secondary anticyclone, and is most evident about 4 a. m., when it prevails over all of South and North America, with a maximum depression of about —0.040 inch.

The position of the centers of the diurnal departures of pressure depend upon the season of the year and upon the relative distribution of land and water.

The westward propagation of the four areas is represented diagrammatically as follows in fig. 3, but is more clearly shown by Plates X to XXXIII.

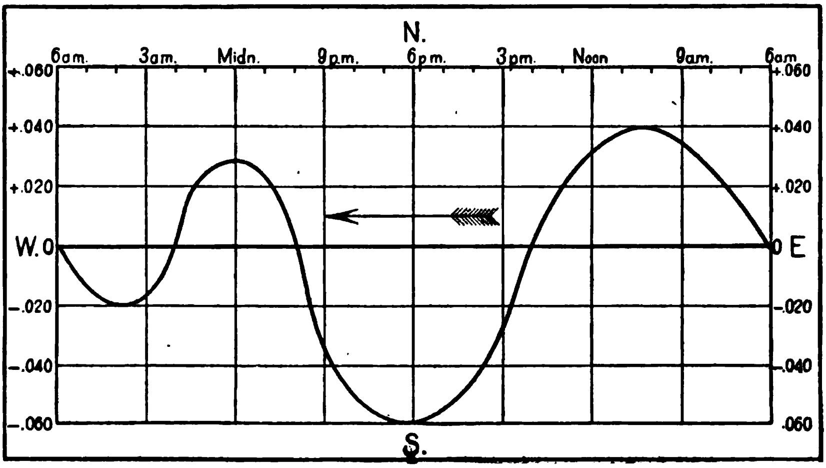


FIG. 3.

Plate X. Diurnal Westward Movement of Barometric Wave. 1 A. M.

1 a.m.

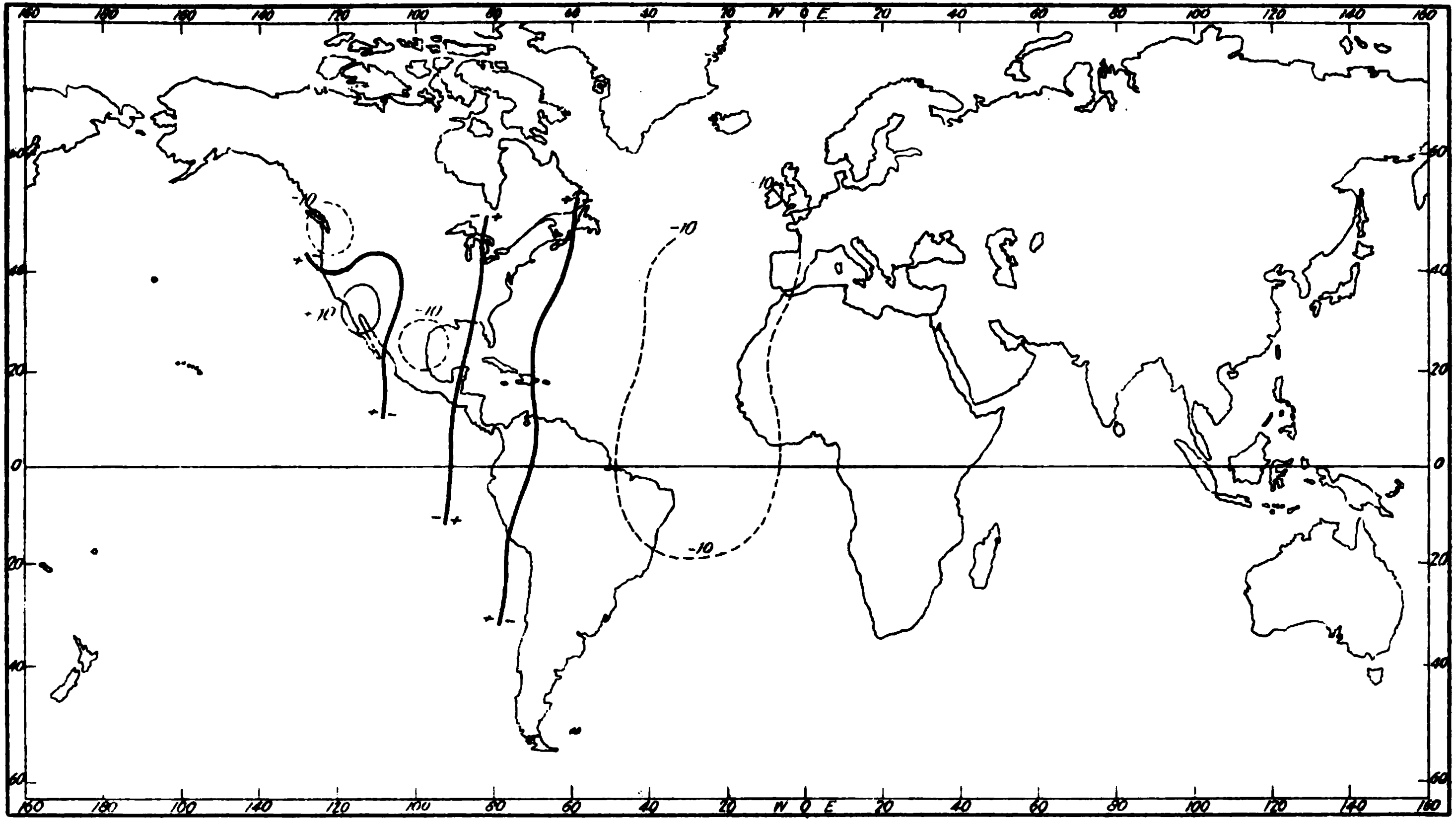


Plate XI. **Diurnal Westward Movement of Barometric Wave. 2 A. M.**

7-a.m.

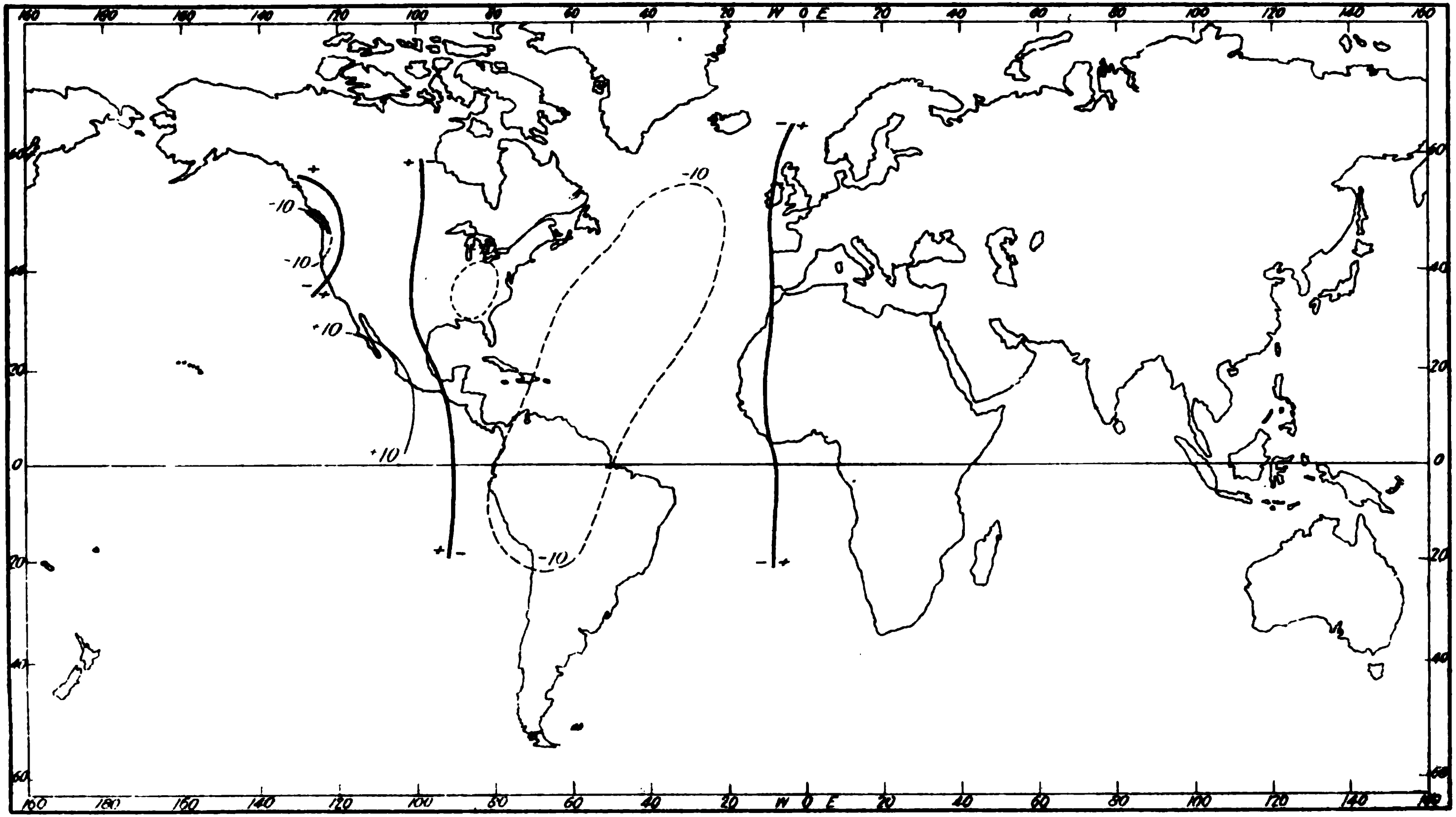
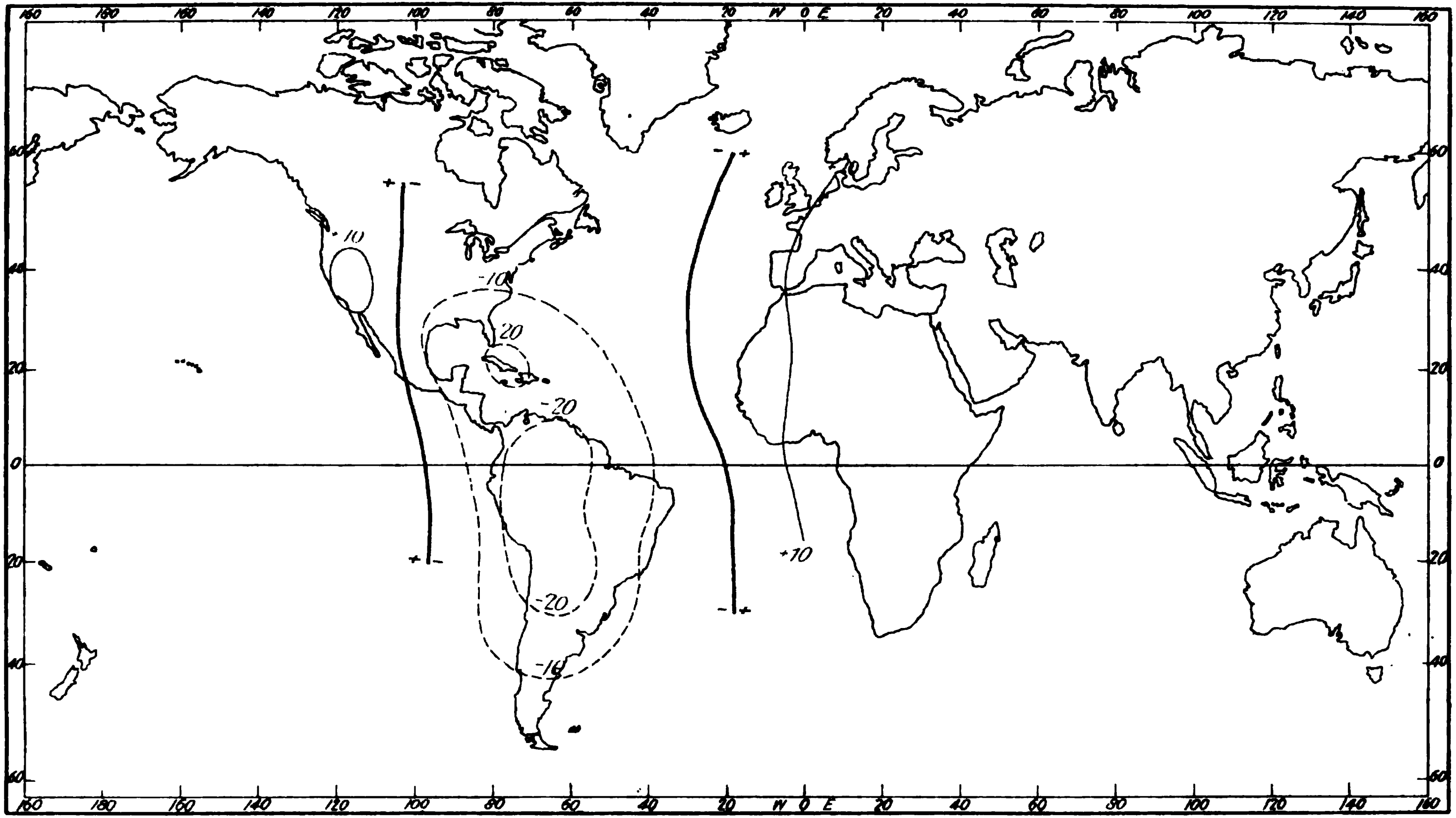


Plate XII. Diurnal Westward Movement of Barometric Wave. 3 A. M.

3-a.m.



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-20
20
-20
-10
+10
+ -
- +

Plate XIII. Diurnal Westward Movement of Barometric Wave. 4 A. M.

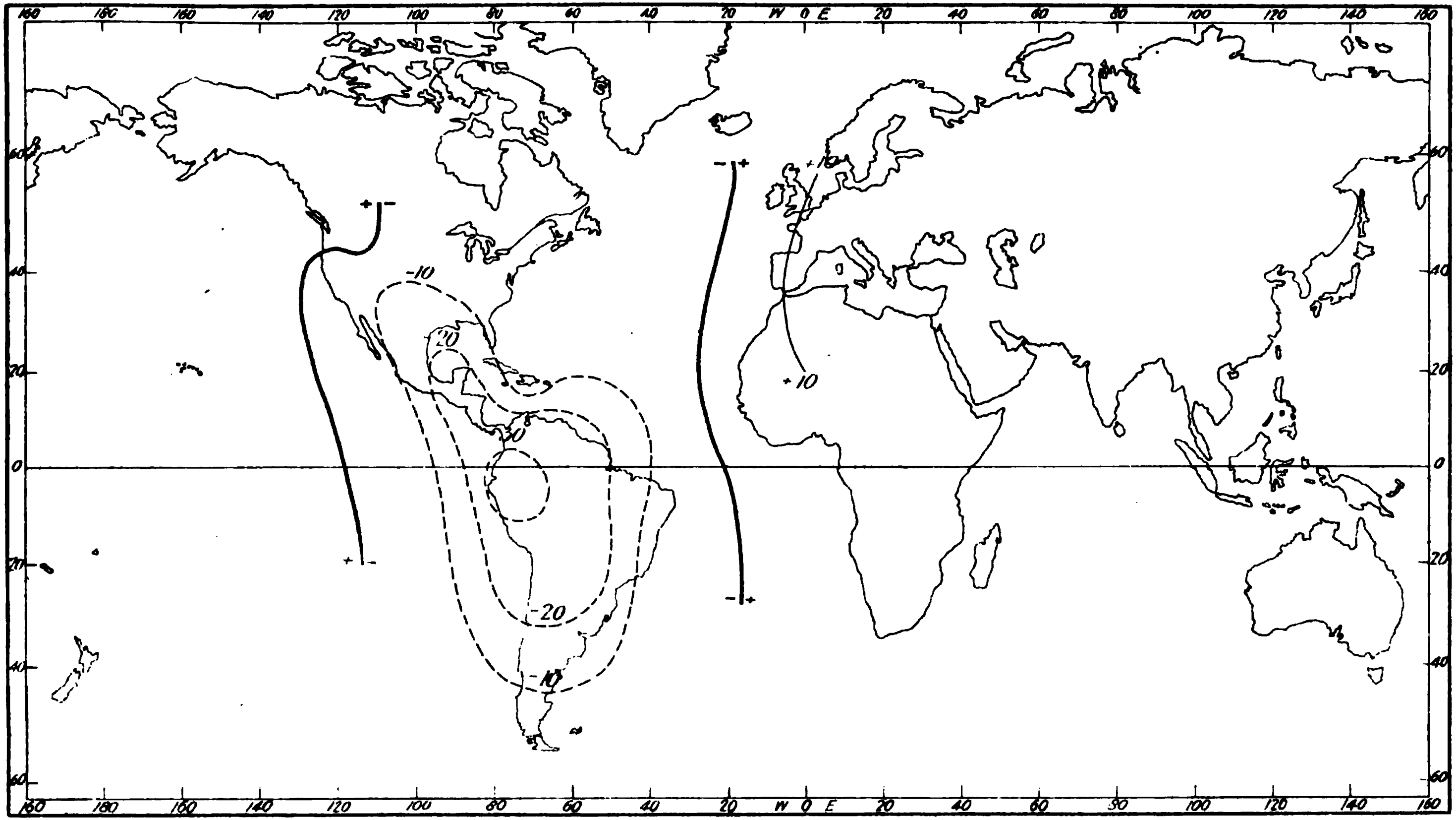


Plate XIV.

Diurnal Westward Movement of Barometric Wave. 5 A. M.

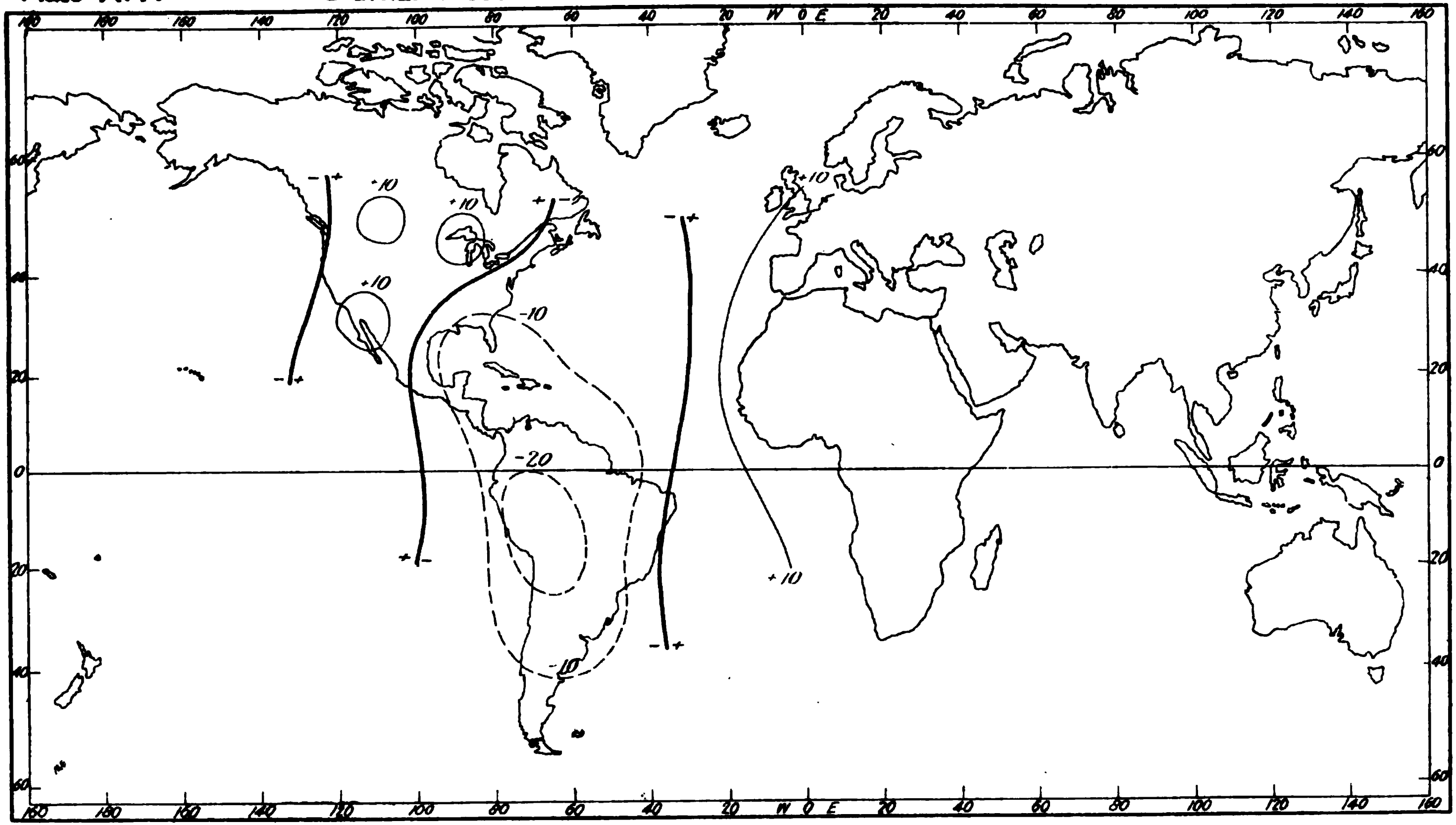


Plate XV.

Diurnal Westward Movement of Barometric Wave. 6 A. M.

6 a m.

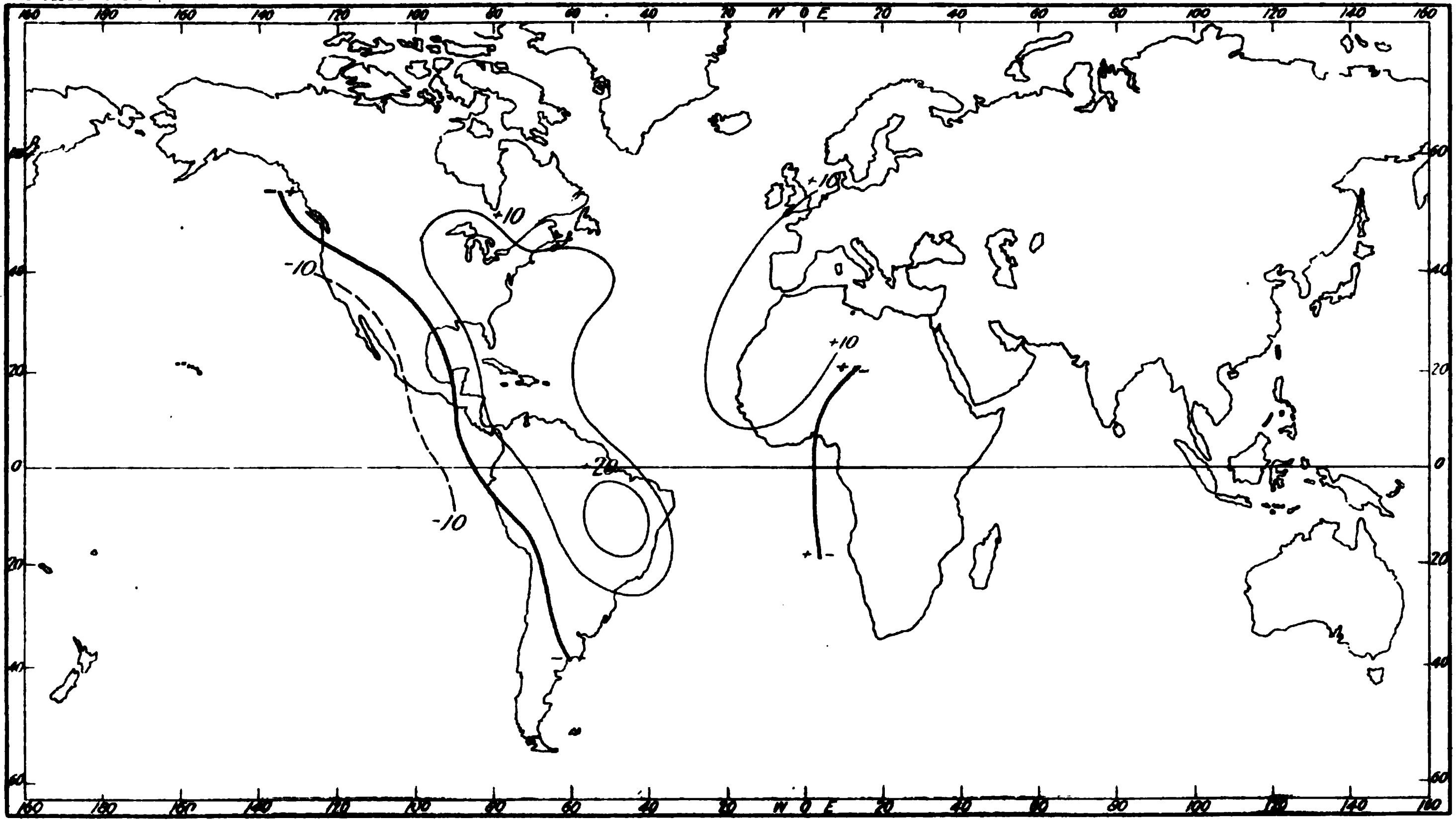


Plate XVI. Diurnal Westward Movement of Barometric Wave. 7 A. M.

7 - a.77V

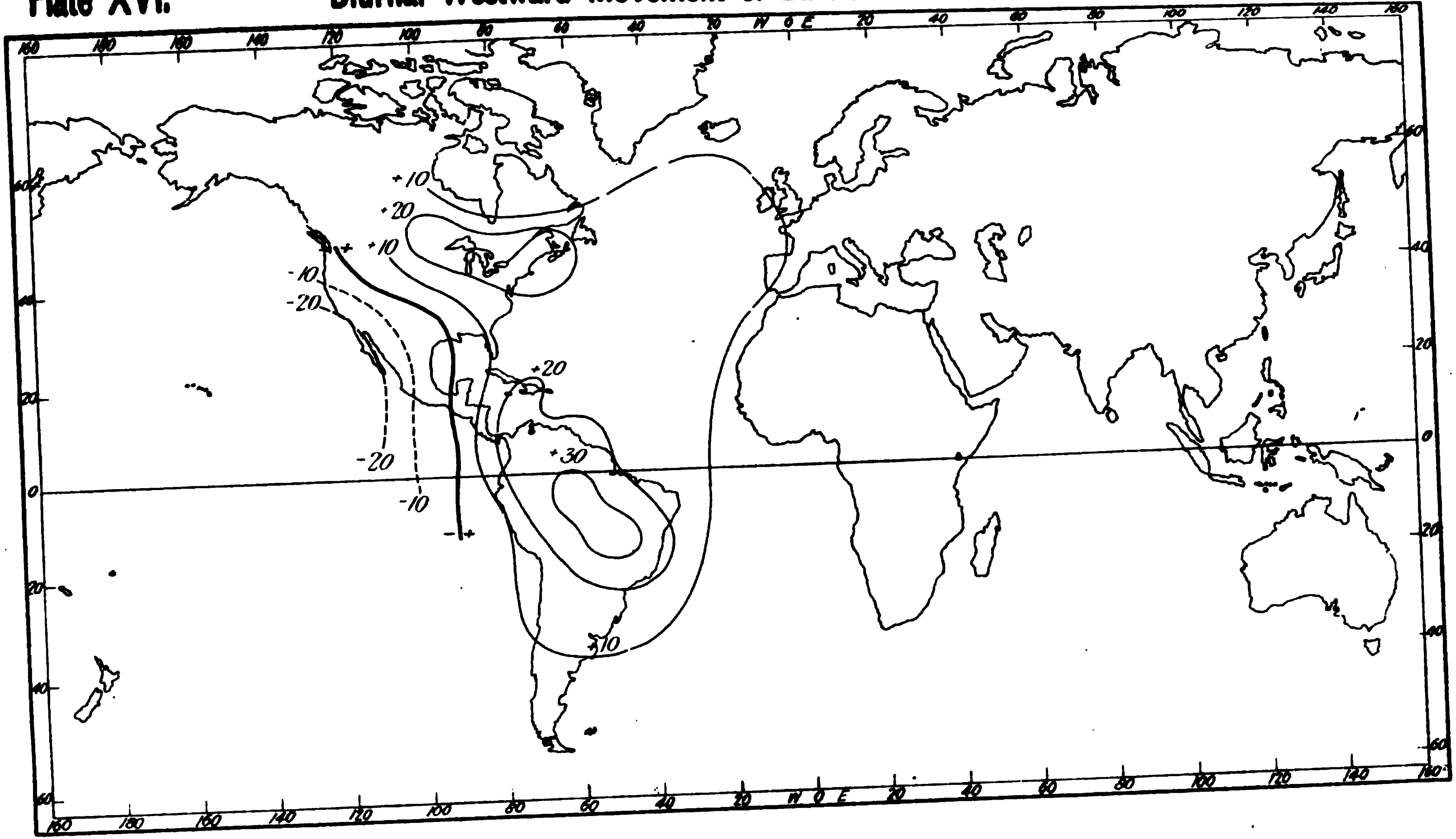


Plate XVII.

Diurnal Westward Movement of Barometric Wave. 8 A. M.

8-a. m

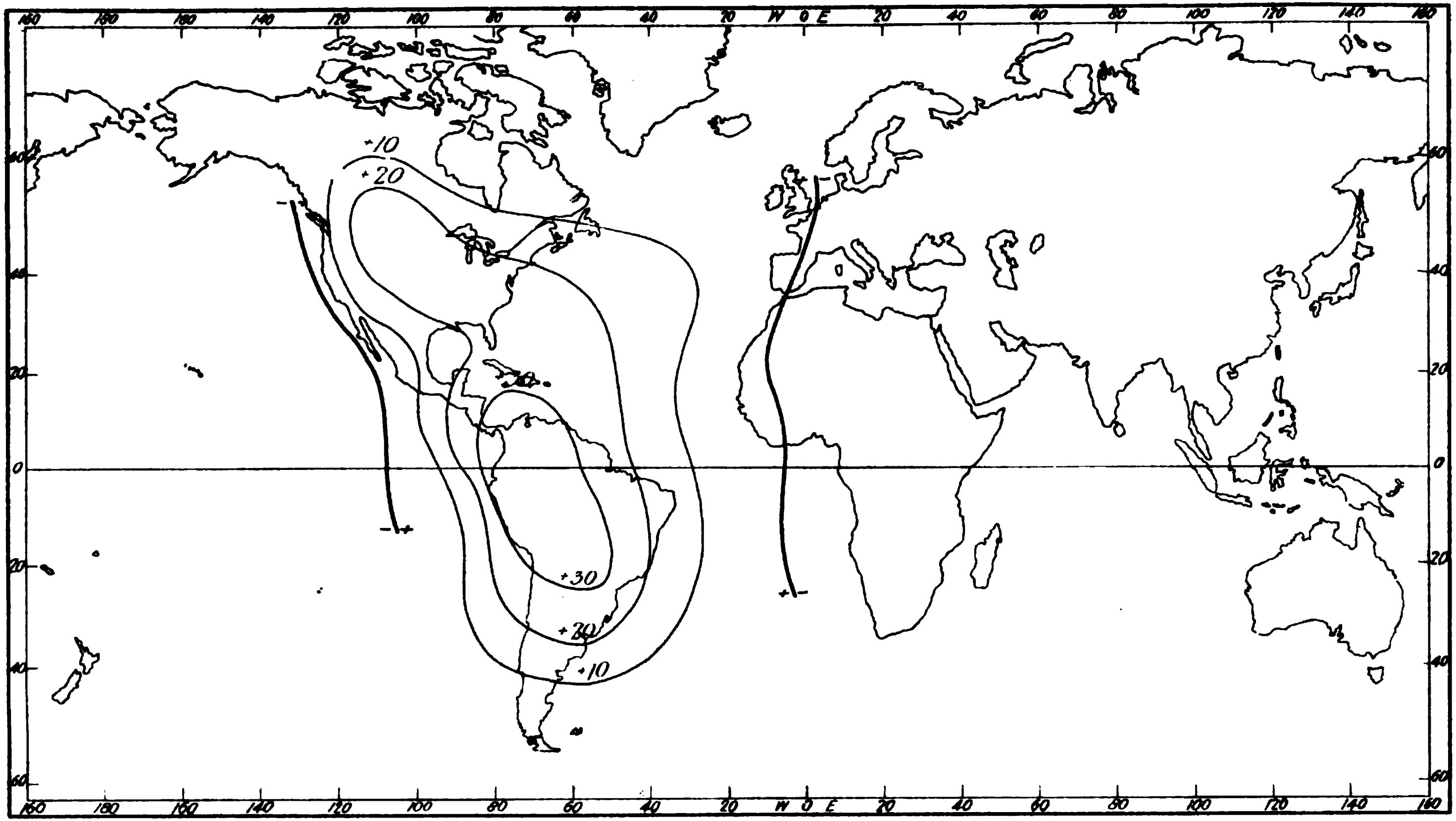


Plate XVIII. Diurnal Westward Movement of Barometric Wave. 9 A. M.

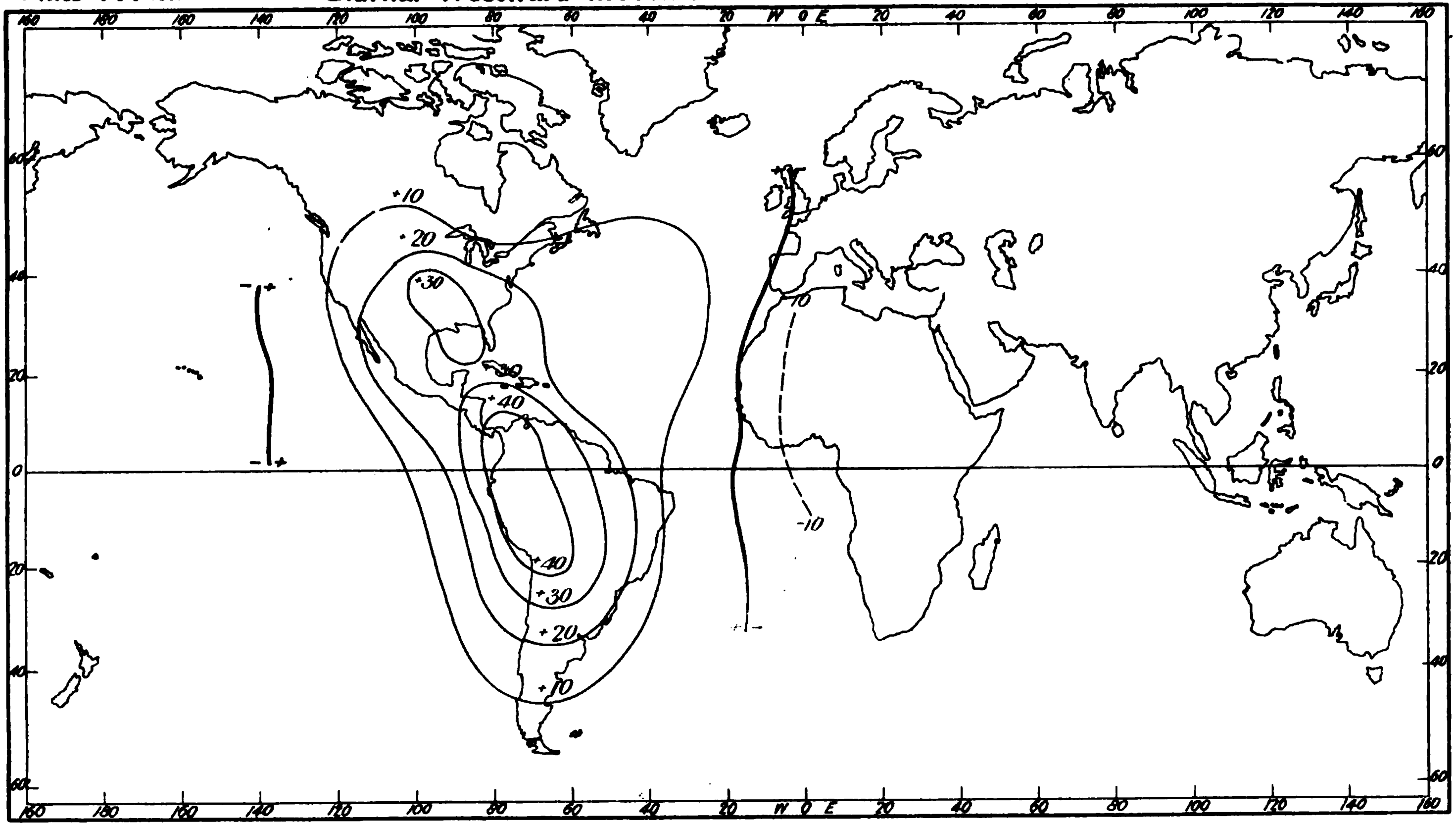


Plate XVIII. Diurnal Westward Movement of Barometric Wave. 9 A. M.

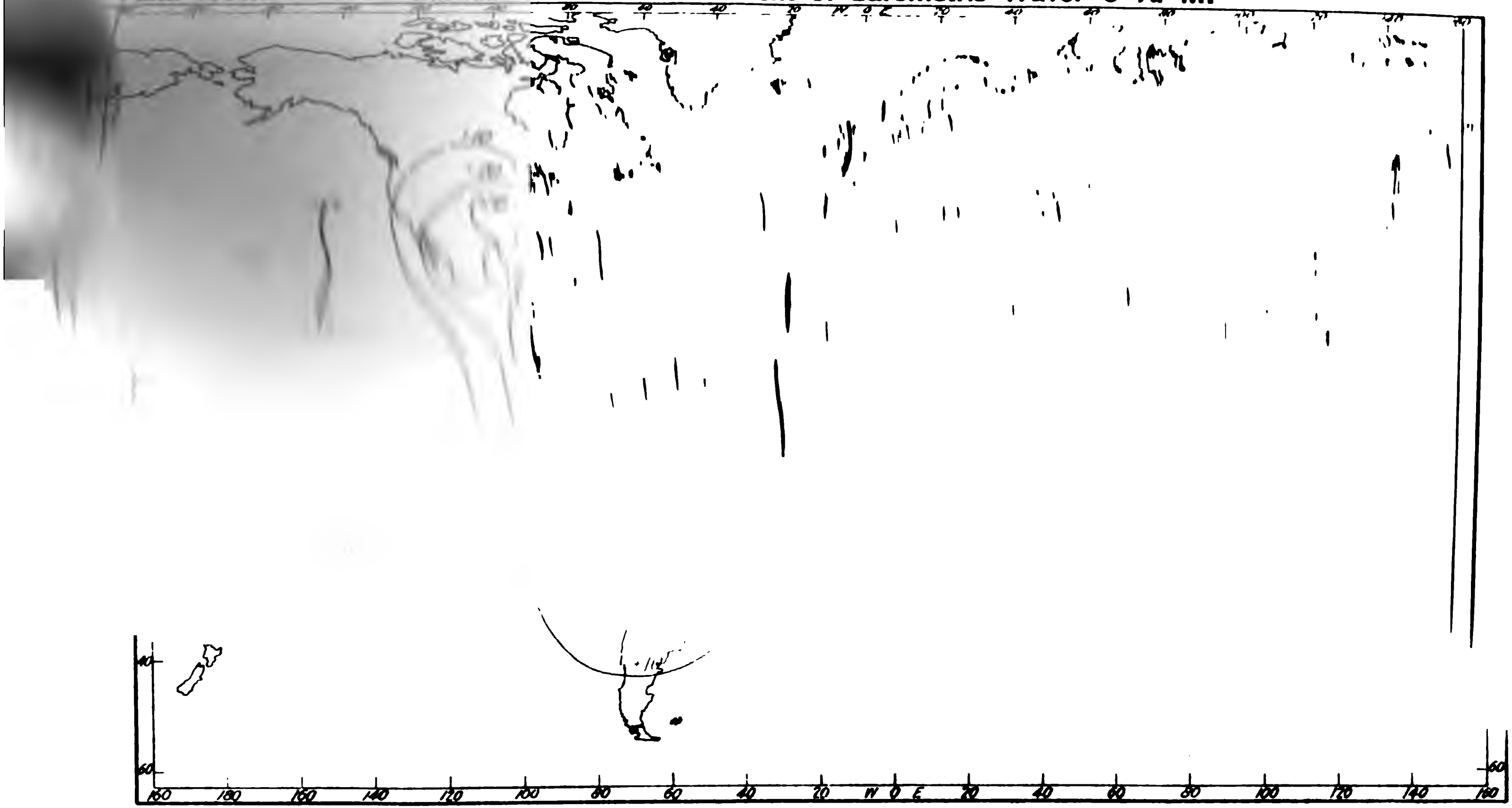
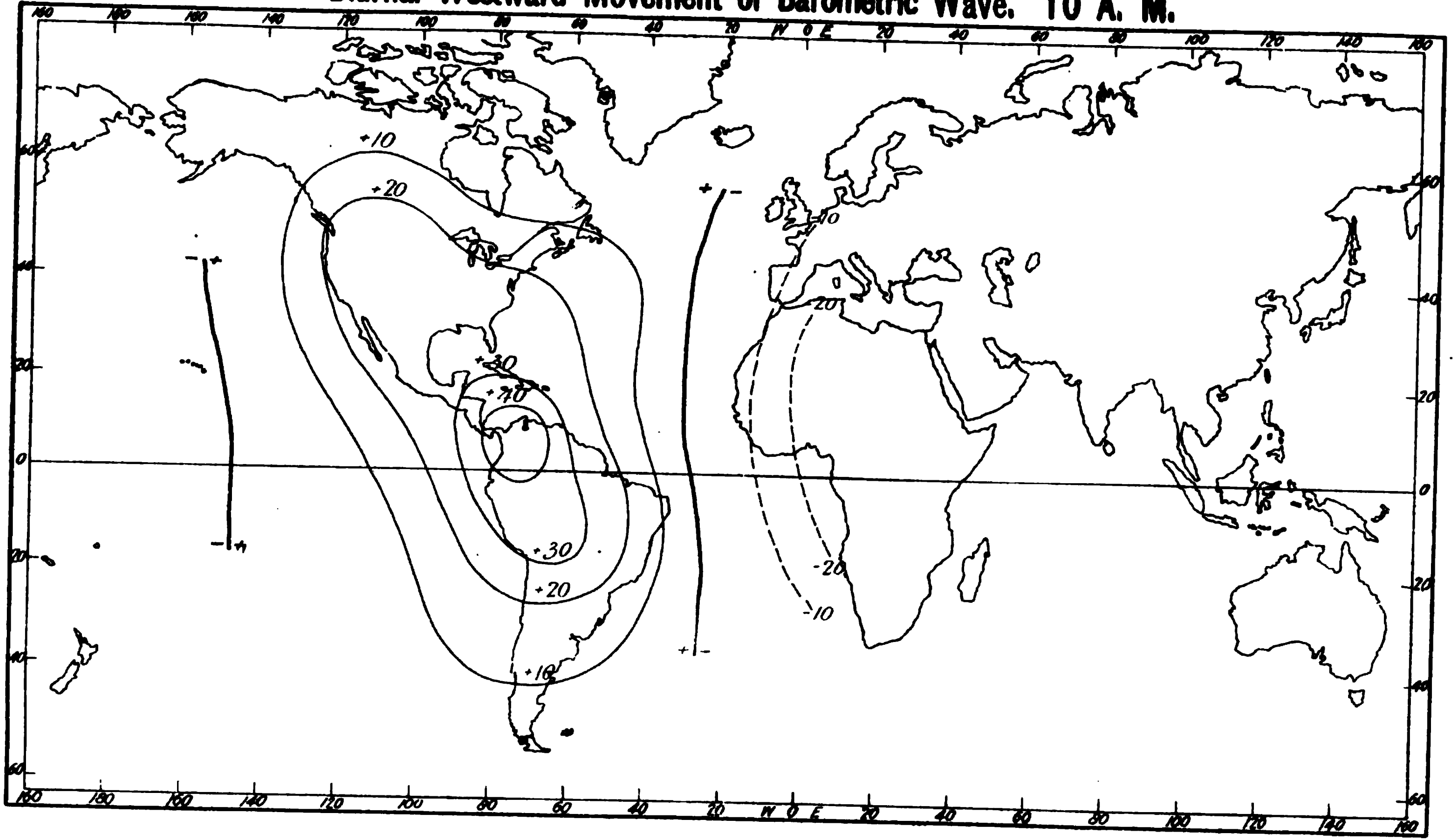


Plate XIX. **Diurnal Westward Movement of Barometric Wave. 10 A. M.**

10 a.m.



11- a.m.

Plate XX. Diurnal Westward Movement of Barometric Wave. 11 A. M.

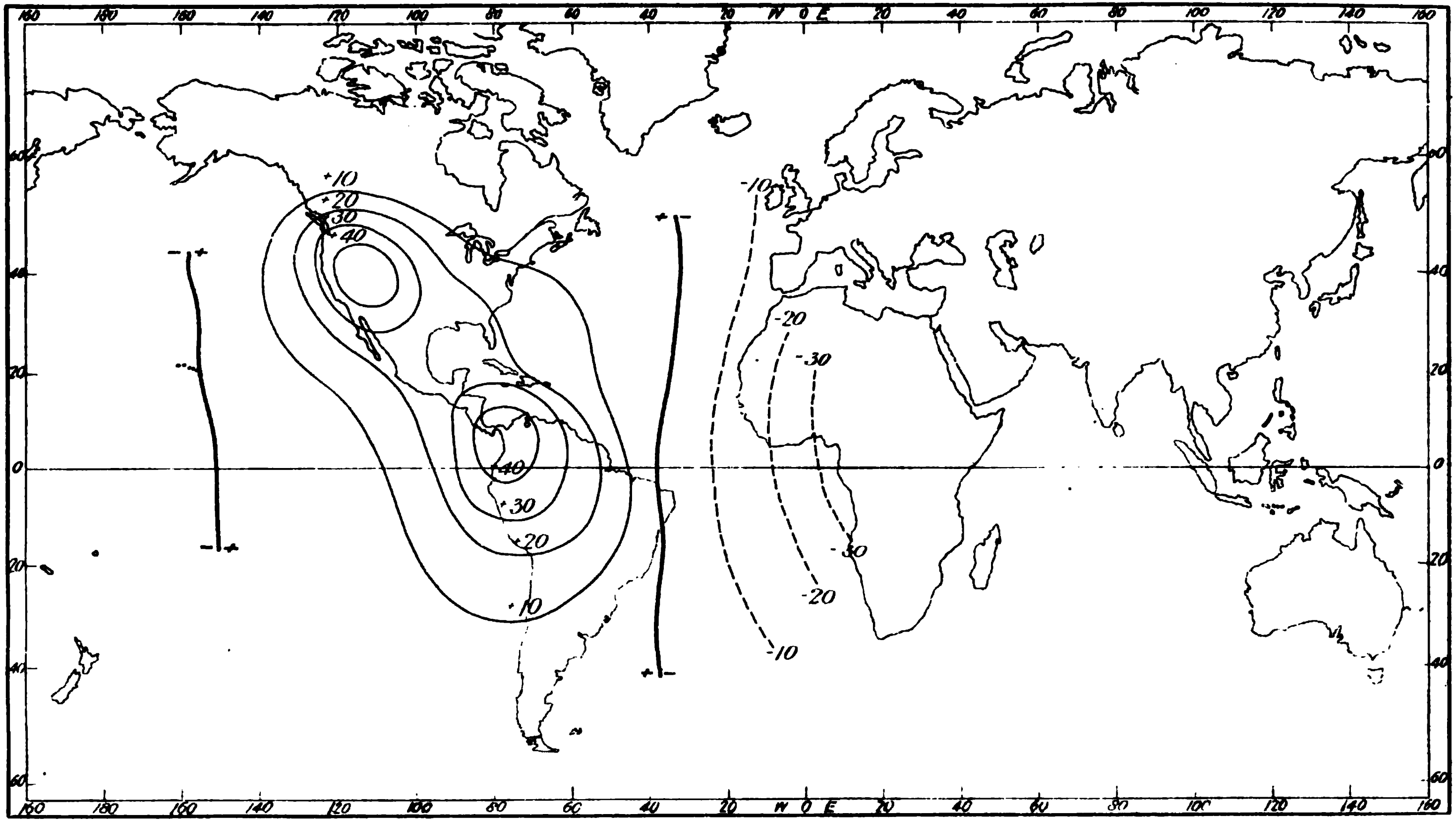


Plate XXI. Diurnal Westward Movement of Barometric Wave. 12 M.

12 Noon

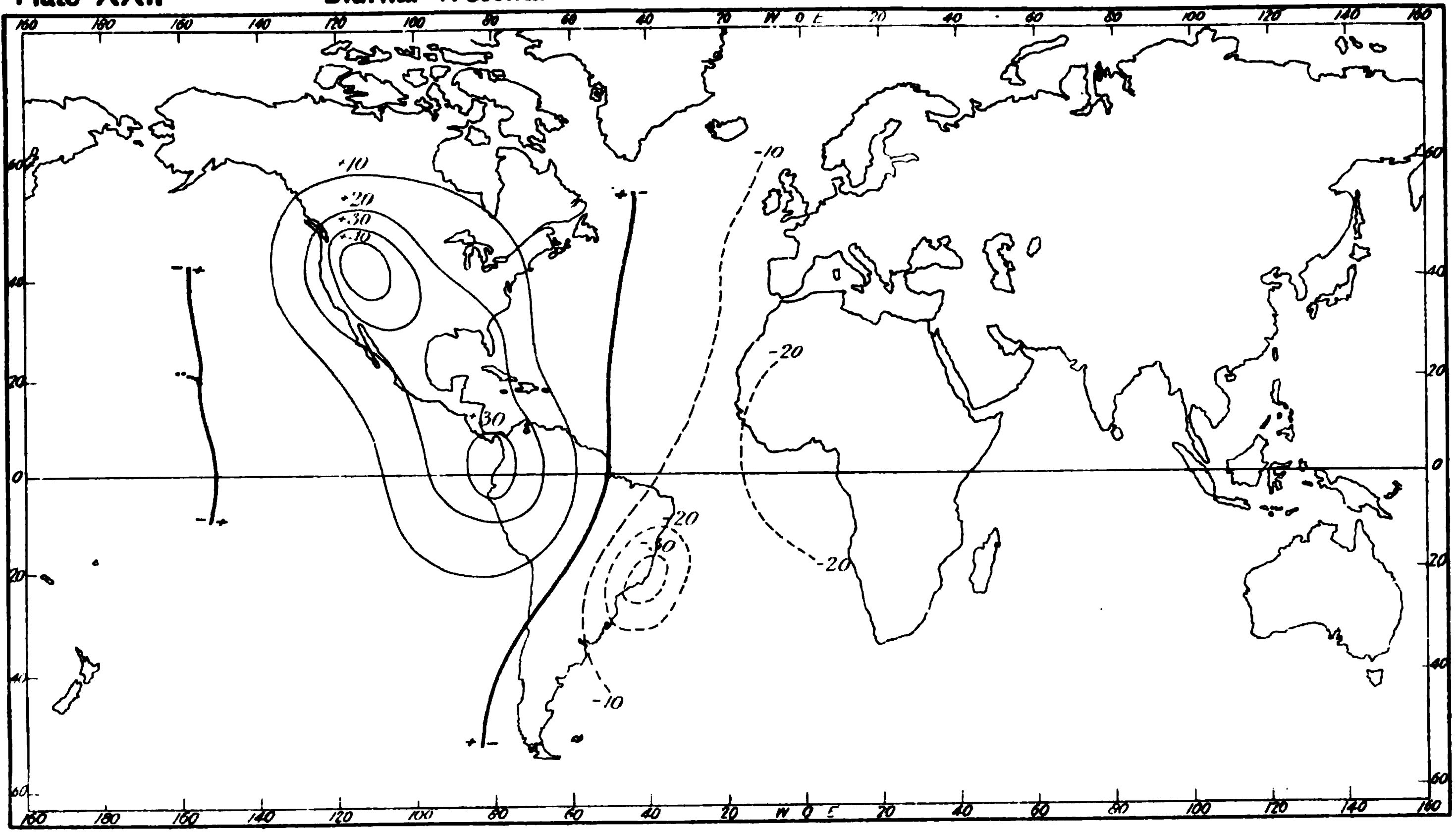
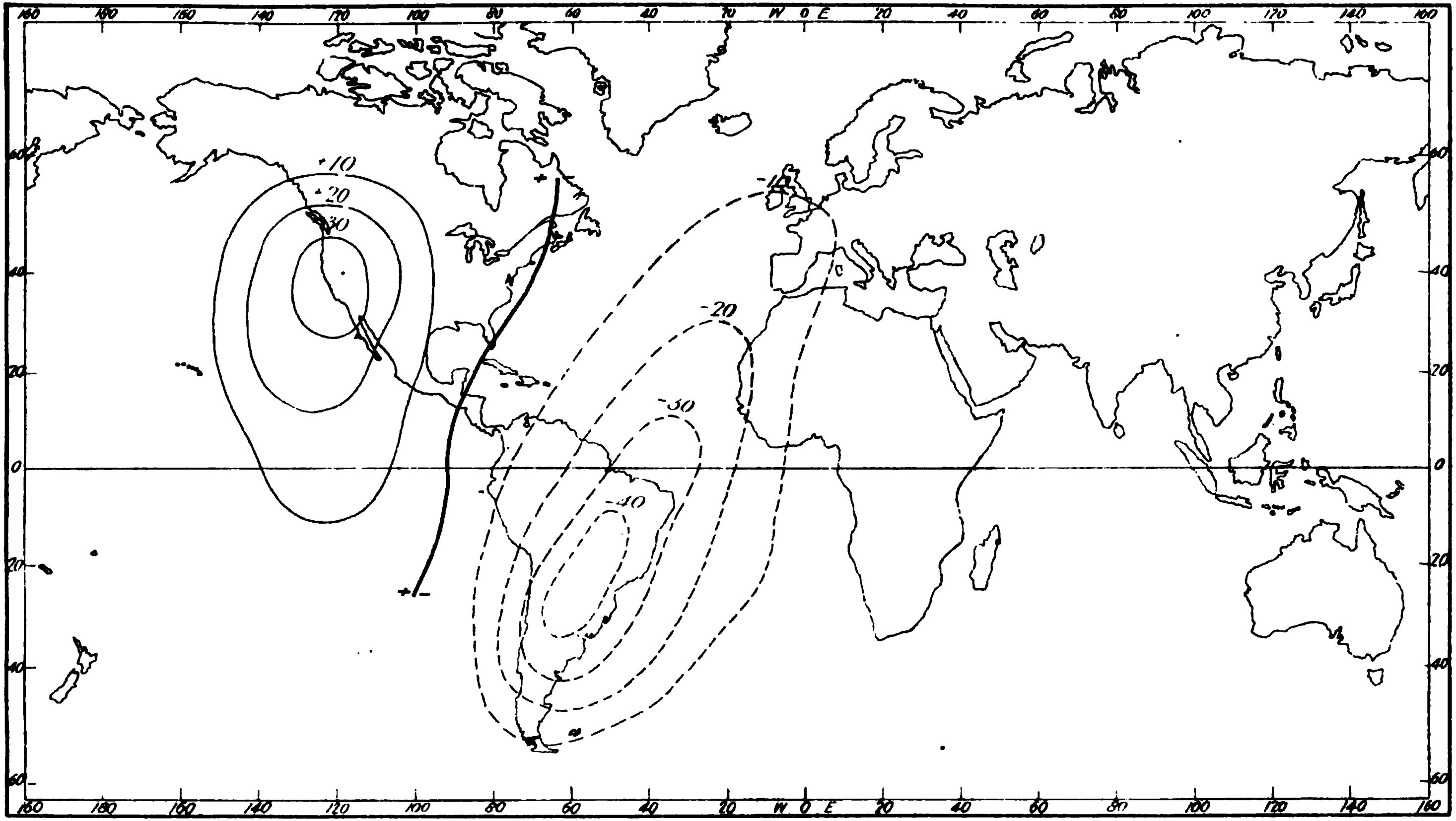


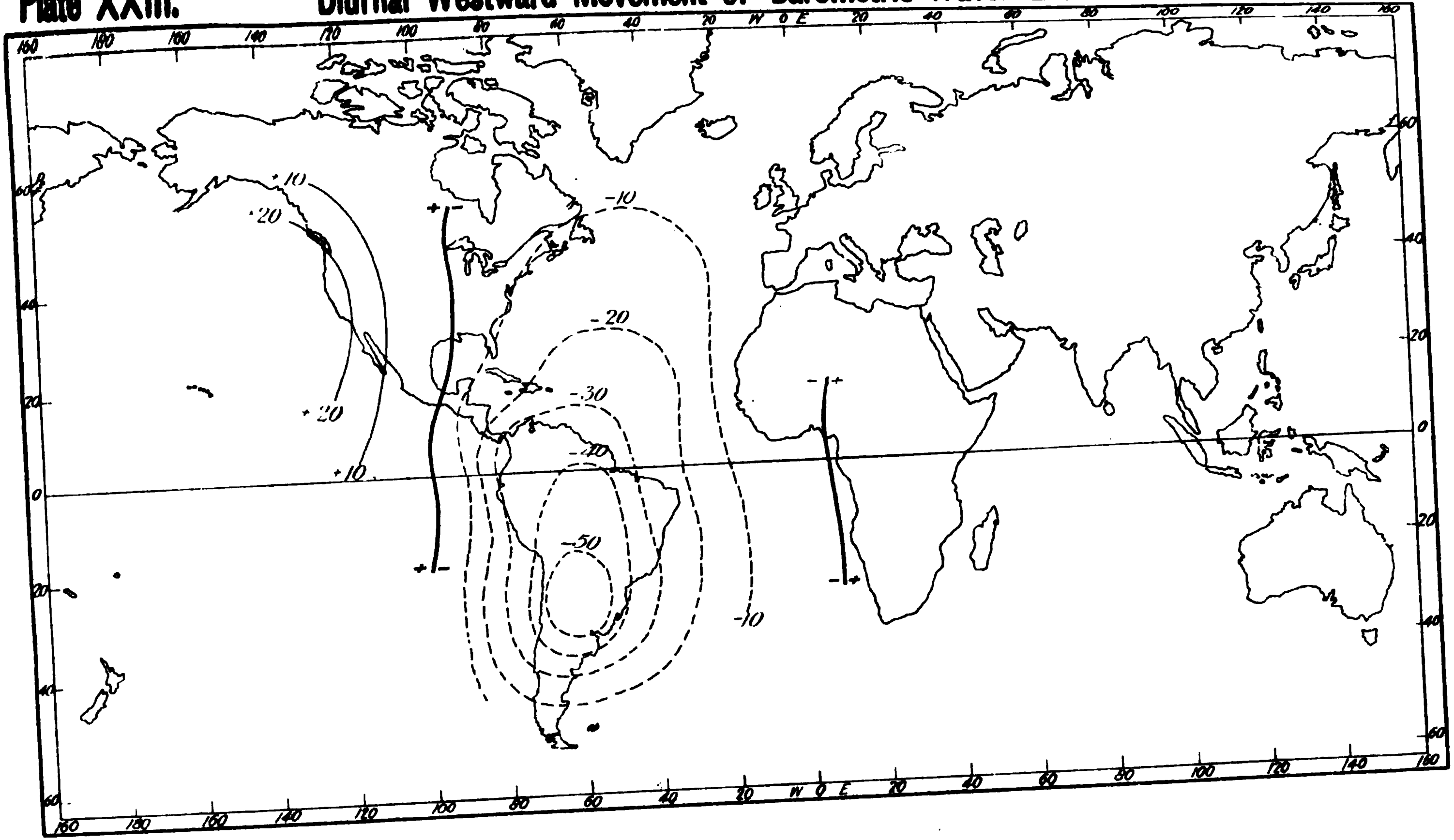
Plate XXII. Diurnal Westward Movement of Barometric Wave. 1 P. M.

1 1' 772



2 p.m.

Plate XXIII. Diurnal Westward Movement of Barometric Wave. 2 P. M.



3-p.m.

Plate XXIV. Diurnal Westward Movement of Barometric Wave. 3 P. M.

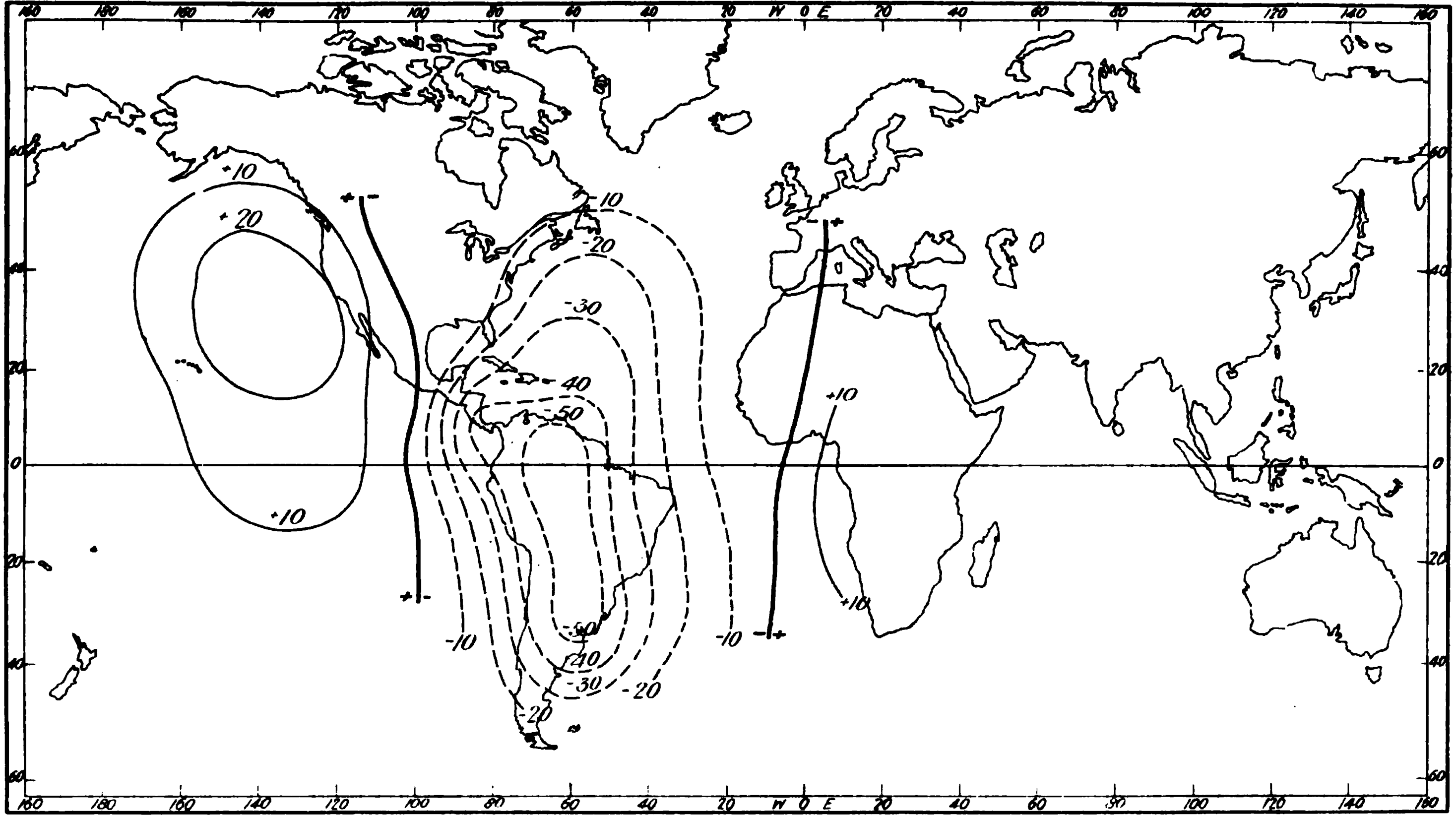


Plate XXV. **Diurnal Westward Movement of Barometric Wave.** **4 P. M.** 4 - p.m.

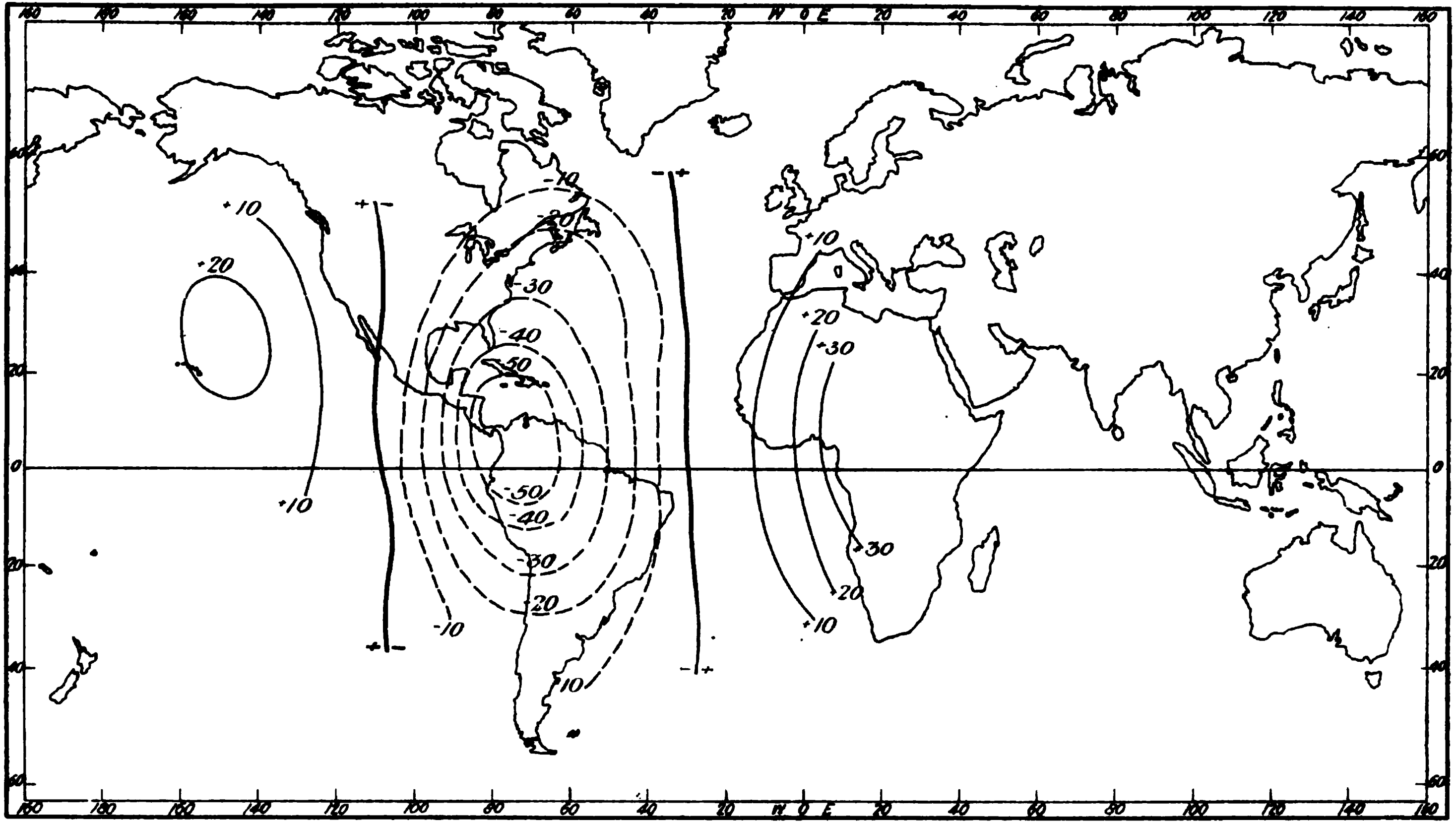


Plate XXVI. Diurnal Westward Movement of Barometric Wave. 5 P. M.

5 pm

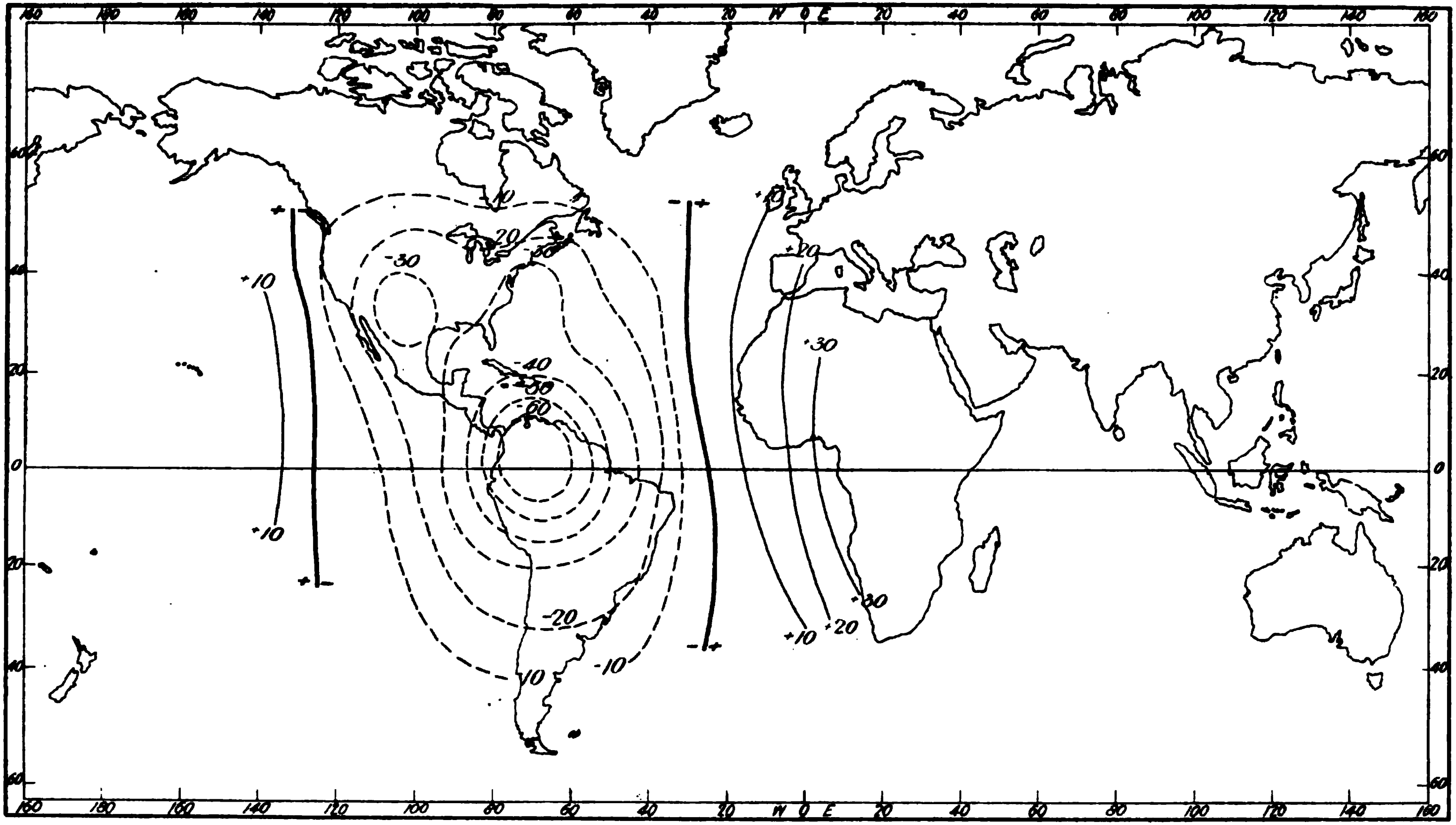
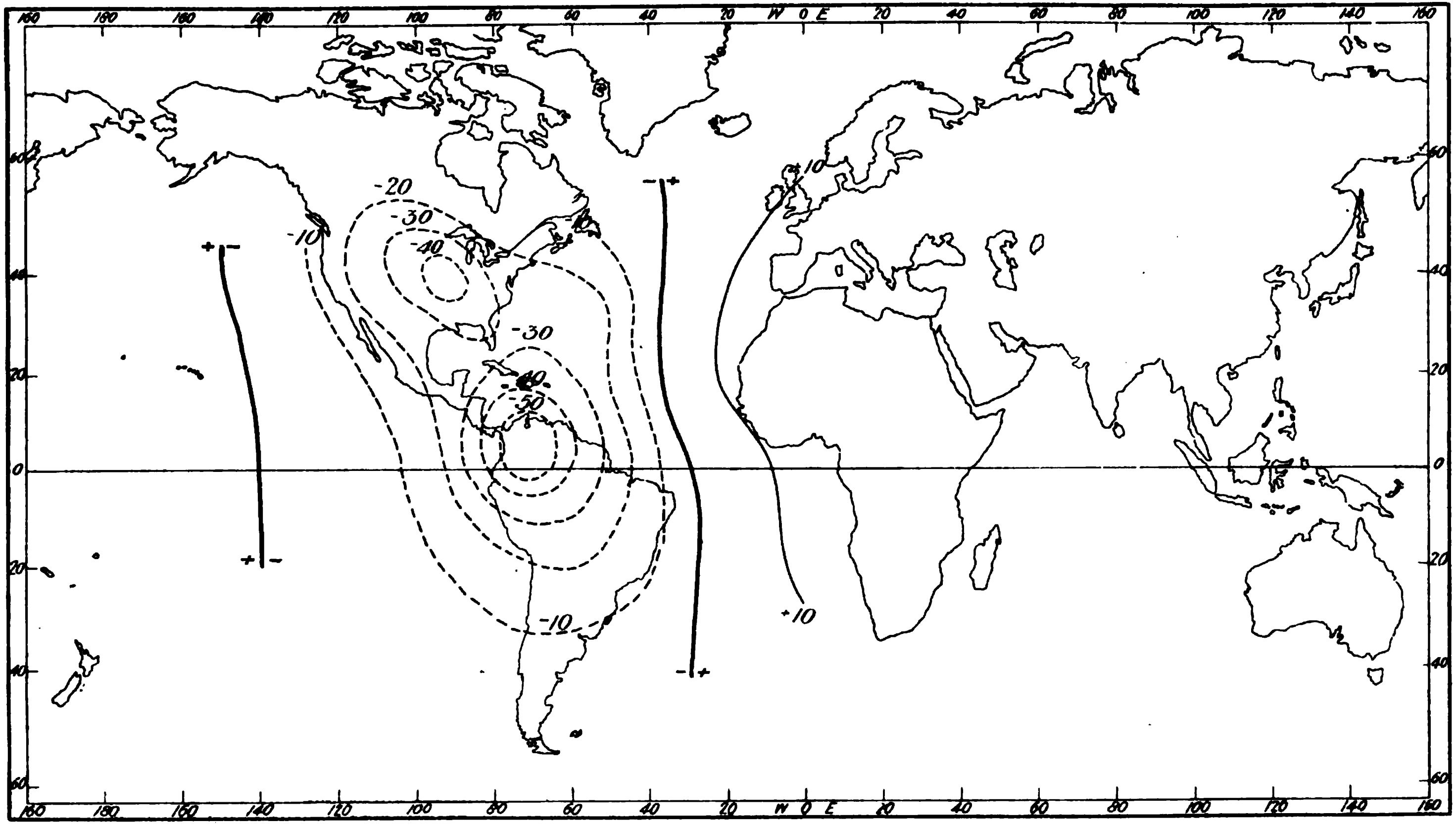


Plate XXVII. Diurnal Westward Movement of Barometric Wave. 6 P. M.

6 p.m.



7 p.m.

Plate XXVIII. Diurnal Westward Movement of Barometric Wave. 7 P. M.

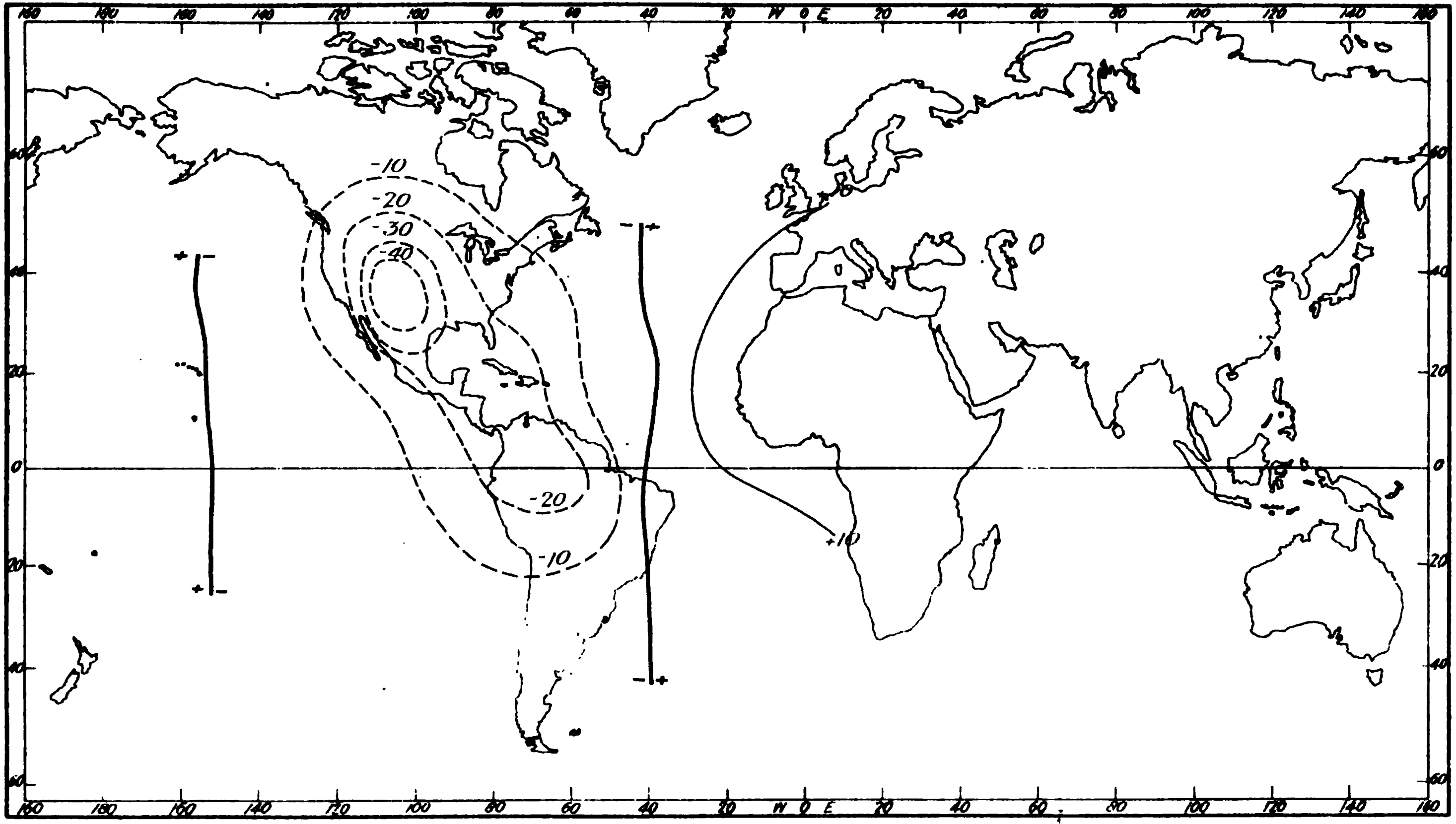


Plate XXIX.

Diurnal Westward Movement of Barometric Wave. 8 P. M.

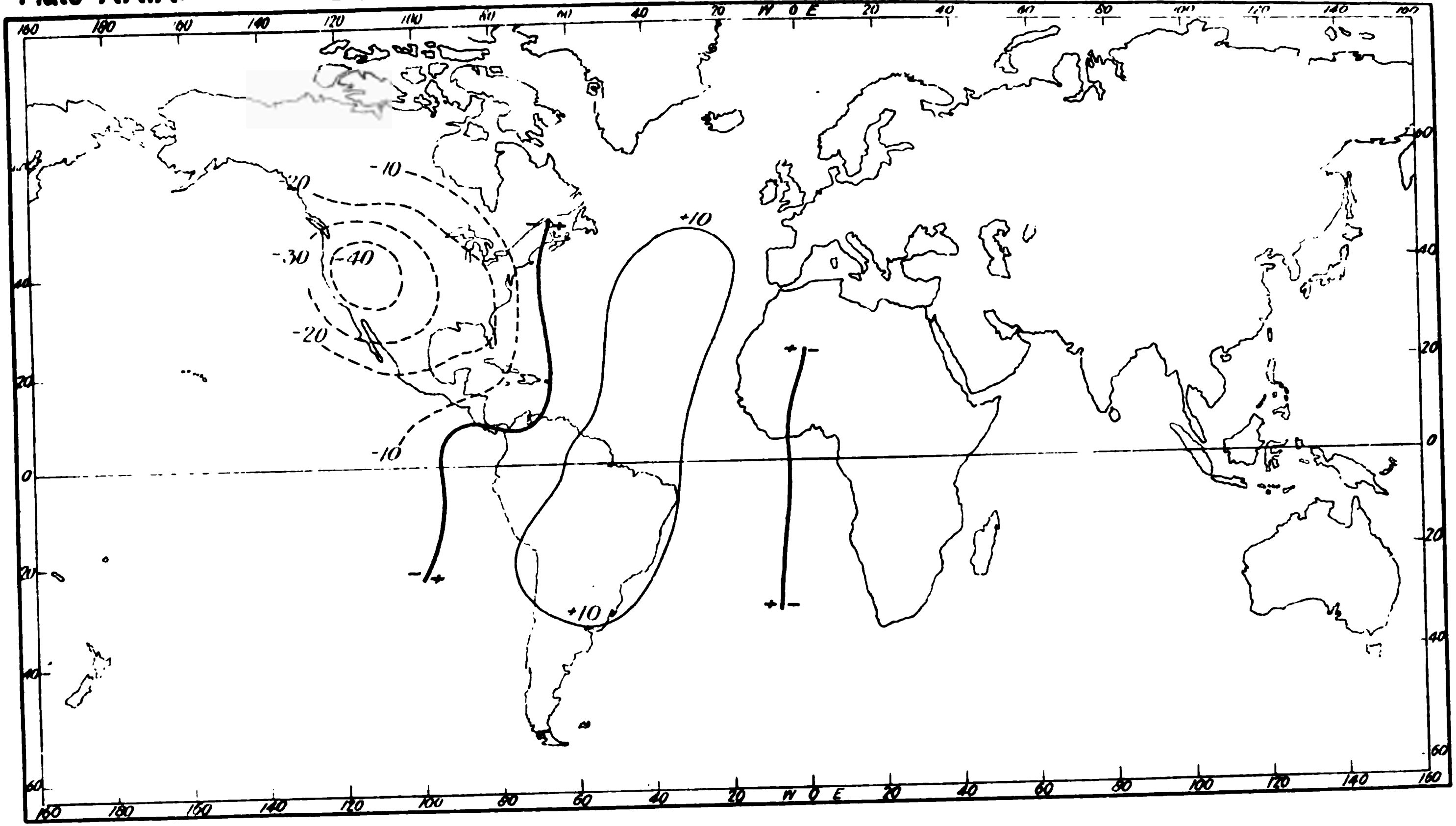
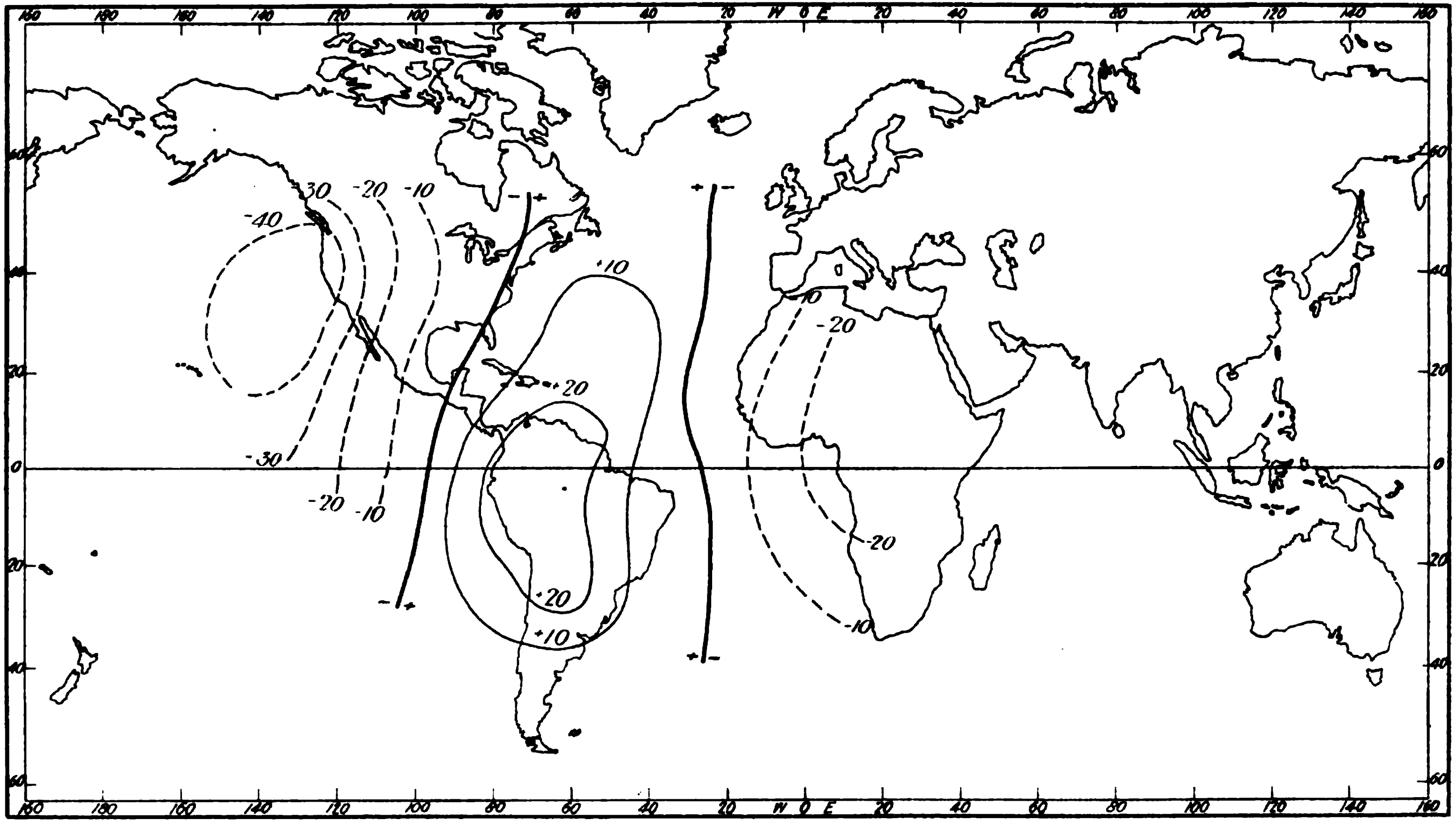


Plate XXX. Diurnal Westward Movement of Barometric Wave. 9 P. M.

9 p m



160 180 160 140 120 100 80 60 40 20 W 0 E 20 40 60 80 100 120 140 160
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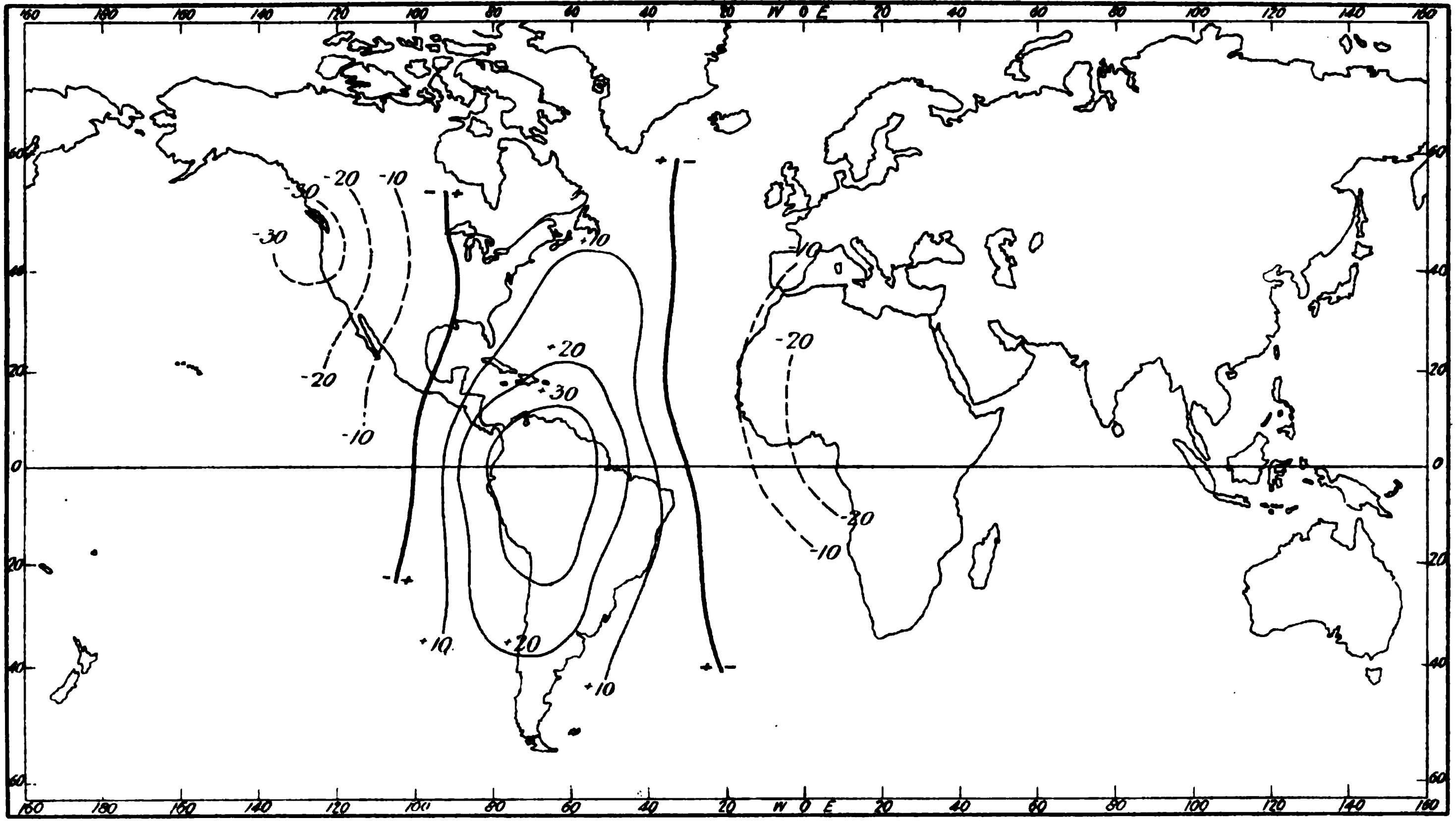
Plate XXXI. Diurnal Westward Movement of Barometric Wave. 10 P. M.

10 - p.m.



11 p.m.

Plate XXXII. Diurnal Westward Movement of Barometric Wave. 11 P. M.

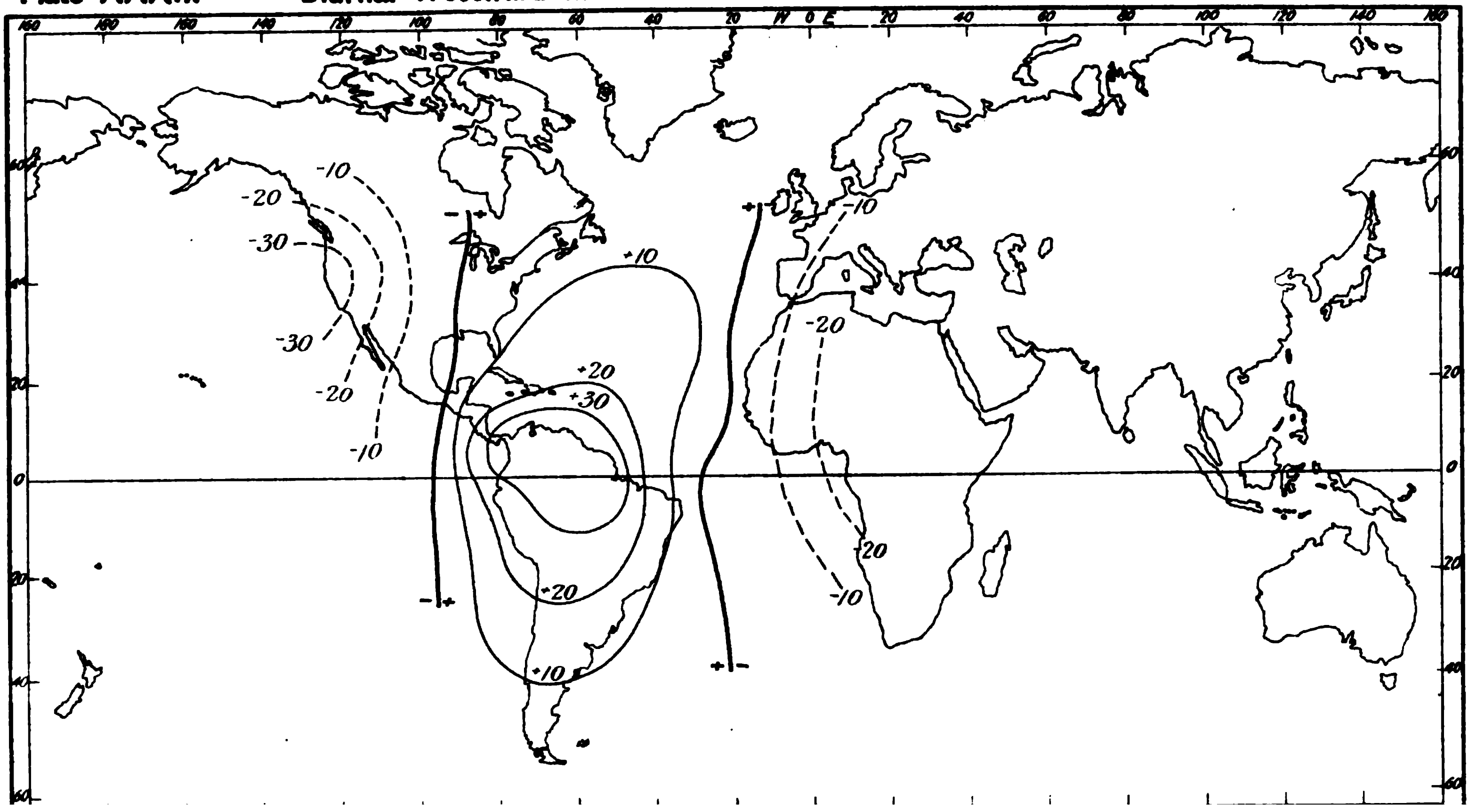
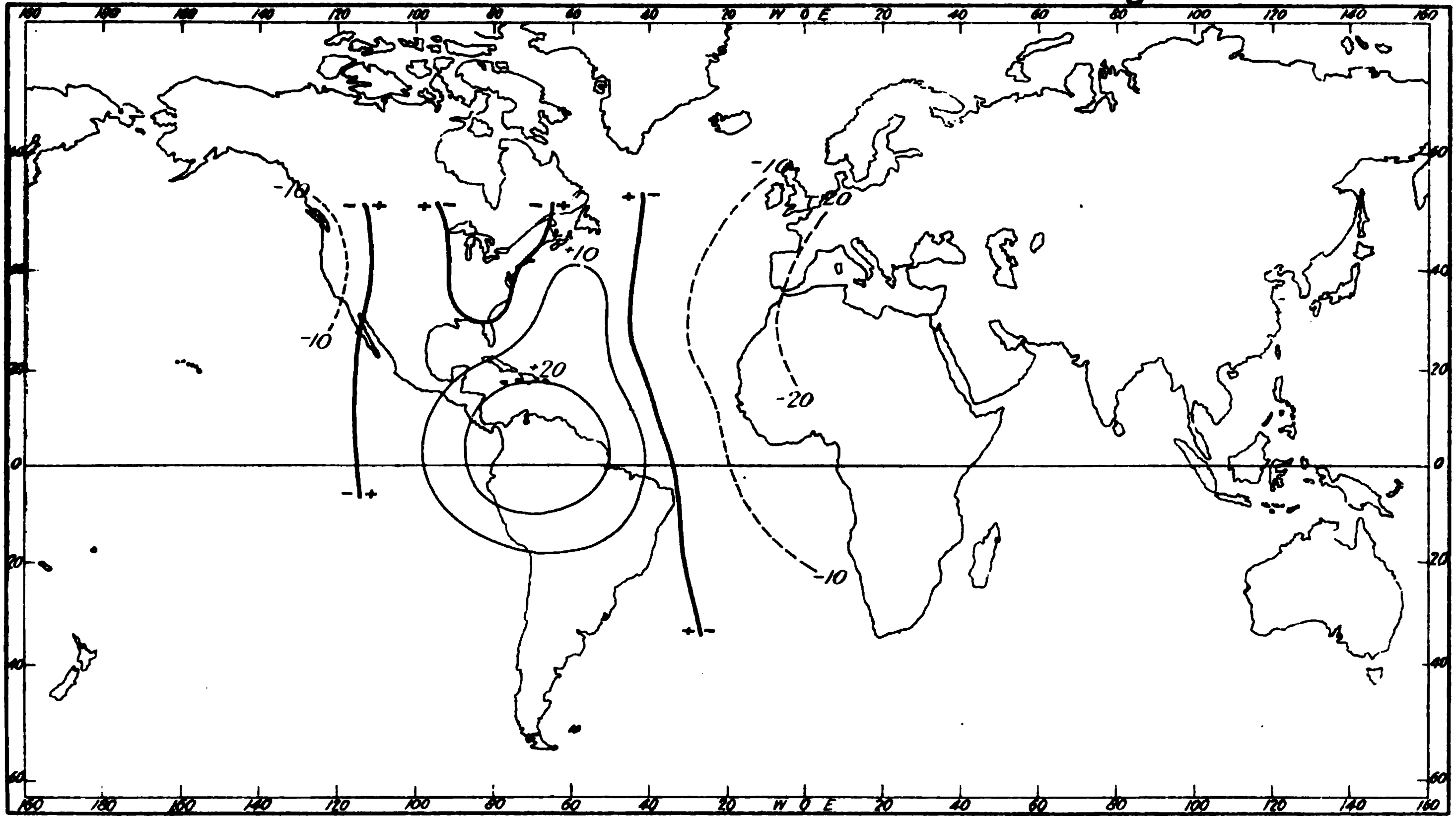


Plate XXXIII. Diurnal Westward Movement of Barometric Wave. 12 Midnight.

12 Mdt



DISCUSSION.

Professor MOORE. This movement is beautifully portrayed by the charts accompanying this paper. Starting at 1 a. m. on the west coast of Europe, at 2 a. m. the barometric wave is in the center of the Atlantic Ocean, and by 6 o'clock it is passing off our western coast into the Pacific Ocean. I think this paper is quite unique and is entitled to great consideration.

Professor BIGELOW. The movement of the diurnal wave is perpetual; still one can observe it at a given locality in successive hours. Of course the true understanding is to be had by platting it on a sphere, instead of taking a small number of hours in succession in the same longitude as the American continents. I think that the movement westward consists merely in the fact that the earth turns eastward, as under a collar. The interesting thing in this paper, which I believe scientists will appreciate, is this: The swing of the axis of the wave is over the continent under certain conditions and over the ocean under others. That points distinctly to the explanation that the effect must be due to a rotation phenomenon. The change of pressure increases under certain conditions at the continents and under others at the oceans. On the whole, I should suppose that the phenomenon is one of rotation and not a movement of the air as such.

Mr. CLAYTON. I wish to call attention to one of the most interesting aspects of this phenomenon to me; that is the extreme rapidity of the movement, whether we consider the earth as moving under the wave or the wave as moving over the earth. It is moving a thousand miles an hour in the equatorial region. Our ordinary storms move only 30 to 40 miles an hour, but this little diurnal cyclone is moving a thousand miles an hour in the opposite direction to that of the ordinary storm. It has very much the same shape as the ordinary cyclones and anticyclones we have on the map, only it moves with a velocity many times as great. I wish you would call attention at your stations to the watching of the daily changes of the wind as these barometric waves swing by. At Blue Hill the daily shifting of the wind is very distinct. In the big cyclonic movements, of course, all these waves are hidden, but the time to observe them is when we have what is called a "flat" map.

A METHOD FOR THE SYSTEMATIC EXPLORATION OF THE ATMOSPHERE BY MEANS OF KITES.

By Mr. A. LAWRENCE ROTCH, *Director of Blue Hill Meteorological Observatory.*

Although the exploration of the air by means of self-recording instruments, lifted by kites, has been in progress at my observatory since 1894, and several hundred flights have been made in almost all weather conditions up to an extreme height of 3 miles; yet, since a wind of at least 12 miles an hour is required to raise the kites, there are certain types of weather, such as anticyclones accompanied by light winds, that can only be studied high above the earth by means of kites when these are sent up in advance of the anticyclone and allowed to descend in the area of high pressure. In 1898 the United States Weather Bureau equipped 17 stations with kites in order to obtain daily observations at the height of a mile for forecasting the weather. The experiment failed because the light winds during the summer prevented flights from being made regularly at all the stations. Nevertheless, information was obtained concerning the vertical gradients of temperature over a wide area in the central part of the United States.

The systematic exploration of the atmosphere above the Continent of Europe has been in progress for several years under the direction of an international committee, of which I am the American member. Ascents of manned balloons and balloons carrying recording instruments only to still greater heights are now made each month in several countries, and kites are used to supplement the observations at the highest altitudes. It frequently happens, however, that on the day of the balloon ascent the wind at the ground is insufficient to raise the kites. Since the balloons drift with the upper currents to considerable distances, the comparison of the data obtained from them with observations made at designated stations on the ground is more or less uncertain.

The method which I have the honor to propose obviates both these difficulties, the chief one being, of course, the necessity of having windy weather to fly the kites, and renders it possible to obtain at nearly all times information about the upper air and this in regions hitherto inaccessible. Briefly stated, it is the employment on steamships of kites carrying meteorographs, especially on vessels cruising in tropical oceans. Kites can be used on shipboard more frequently and to better advantage than on land, since they can almost always be flown from a stationary or a moving ship. For example, when the air is calm, by steaming through it at a speed of 10 or 12 knots the kites can be raised easily to the height that they would reach in the most favorable natural wind, and, on the contrary, the force of strong winds can be reduced if the vessel moves with the wind. Often, while there is sufficient wind near the surface, it fails entirely at the height of the cumulus clouds, and in this case it would only be necessary to put the ship in motion to carry the kites through the calm zone and into the upper current that may suffice to lift them.

To make these observations properly requires a vessel that can be started, stopped, and turned at the will of the meteorologist, who may thus explore the heights of the atmosphere, just as the hydrographer and zoologist have explored the depths of the ocean. Had the *Challenger* on her cruise around the world been provided with our modern kite apparatus and accompanied by meteorologists trained in its use, it might have accomplished the double task of sounding the oceans of air and water. The German antarctic vessel *Gauss* is equipped with meteorological kites, which will be used on the southern voyage just begun, but it is to be feared that this branch of the meteorological work, being subordinate to the main aims of the expedition, will always be sacrificed to them. Dr. Gregory, who was to have been the scientific head of the English antarctic expedition that has recently sailed on the *Discovery*, intended to employ kites at the polar station, and last year visited Blue Hill to examine our installation.

The storage and handling of kites on steamships seem to present no serious difficulty, for power is available at all times to operate the kite winch and the wire from it may be led over a pulley on a yardarm, capable of being turned so as to bring the kites clear of the rigging, etc. The launching of a kite from a ship would be easier than on land, owing to the greater steadiness of the winds at sea. Wherever the observations in the upper air may be made, there is always the observing station on the ship not far distant horizontally with which to compare them. Although observations above all the oceans are valuable, the equatorial region is the most important to be explored, for, with the exception of a few observations on the Andes and on mountains in central Africa, we know nothing of the thermal conditions prevailing a mile or two above the equator. The importance of such data to complete our knowledge of the thermodynamics of the atmosphere was stated by the Russian meteorologist Woeikof at the meteorological congress at Paris last year. Within the trade-wind belts, north and south of the equator, kites might be employed to determine the height to which the trades extend and also the strength and direction of the upper winds, concerning which the high clouds that are rarely seen in those latitudes give us what little information we now possess.

The atmosphere above the equatorial oceans can be best explored by a vessel having a speed of not less than 12 knots and possessing sufficient deck room to permit of handling the kites. A boat suitable for the purpose is the *Princess Alice*, the exploring yacht of the Prince of Monaco, who has manifested interest in my project. Meanwhile the German meteorologist Köppen is proposing to make observations with kites from a sailing vessel bound across the equator, but it is evident that the main advantage mentioned would be lost on a vessel driven by the wind. In any case it must be remembered that scientific kite flying requires practical and skillful operators, and without them and much reserve apparatus will yield mediocre results.

This use of kites on a vessel that could be maneuvered at will was demonstrated by me on a towboat in Massachusetts Bay on August 22, 1901. Anticyclonic weather conditions prevailed, and the velocity of the southeast wind at sea level varied between 6 and 10 miles an hour, but at no time was sufficient to raise the kites either there or at the Blue Hill Observatory. The maximum speed of the towboat was 10 miles an hour, but by altering the course of the boat with respect to the wind, an artificial wind of 0 to 18 miles an hour was created, the angle through which the boat could be turned and still provide sufficient wind for the kites being about 90°. The uniformity of the artificial wind facilitated launching the kites, which rose with great steadiness at a high angle, carrying the meteorograph to an elevation of half a mile. I shall next endeavor to obtain meteorological data with kites on a steamer crossing the North Atlantic.

(The eminently satisfactory results of this voyage are described in "Science" of December 6, 1901, and reprinted in the Monthly Weather Review for December, 1901.)

A MARKED RISE IN THE NORMAL BALTIMORE TEMPERATURE CURVE FOR MAY.

By Mr. OLIVER L. FASSIG, Ph. D., *Baltimore, Md.*

[Read by title.]

In European literature on meteorology, we meet with frequent reference to certain periods of regression of temperature in spring and early summer, periods during which the steady seasonal advance is checked by a reversion lasting three or four days. One of these periods has received the attention of many writers during the past twenty or more years, namely, the three days from the 11th to the 13th of May. There are other similar days, but these, occurring at a critical period in the growth of vegetation, are more feared by the husbandman in Central Europe than those occurring earlier or later when the dangers of frost are less. The three days most liable to frost, in the estimation of the people, are usually referred to as "The three frost saints," or by some similar popular phrase.[a]

The phenomenon has received the attention of the foremost European meteorologists, and is based upon something more than a popular belief in the occurrence of injurious frosts at this time. The explanation is found in the usual development at this time of a barometric depression over southeastern Europe, in conjunction with the appearance of an area of high pressure over the North Sea, this distribution of pressure causing north to northeast winds and clear nights, with rapid nocturnal radiation, over Central Europe.

Within the past month the writer has constructed a normal curve of temperature for Baltimore, based upon the daily mean for the past thirty years (1871–1900). Upon completion of this curve, the portion representing the month of May was the first to be examined, with the hope of finding in it some trace of a departure similar to that so familiar to European meteorologists. The expected fall in temperature is not to be found in the Baltimore curve; in its place, on the contrary, there is a sharp, well-defined rise from the 9th to the 12th, amounting to 3 or 4 degrees above the average of the 8th and 13th, as illustrated in fig. 4.

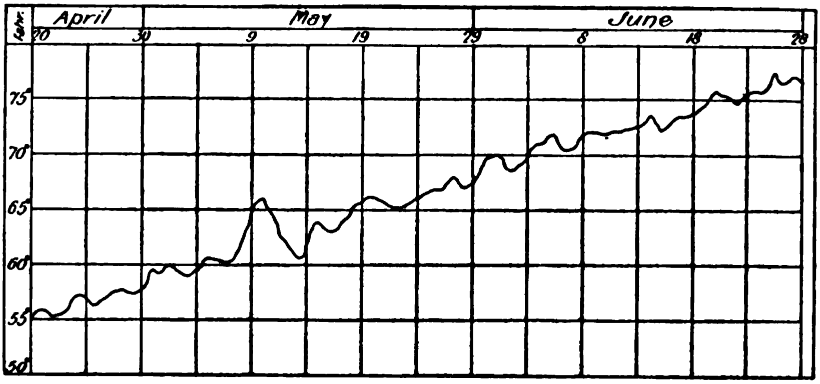


FIG. 4.

A temperature departure which persists to such an extent in a curve smoothed by thirty years of accurate daily observations is a significant feature of the local climate. The writer has had no opportunity as yet to investigate the geographical extent of this departure, or the peculiar distribution of atmospheric pressure to which it is probably due, but it will doubtless be found to extend over a large area, and to be associated with the appearance of the summer type of pressure distribution, namely, the development of a high area over the South Atlantic States, or rather the westward extension of permanent area of high pressure over the North Atlantic, giving rise to a short period of light southwesterly winds and clear skies. This type does not recur regularly on the same days of the month, but the sharp rise in the normal curve from the 9th to the 12th shows a decided tendency to appear at this time.

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[a] "Kälterückfulle in Mai."

THE ADVENT OF SPRING.

By Mr. CHARLES F. VON HERRMANN, *Raleigh, N. C.*

[Read by title.]

Our genial poet and philosopher, Oliver Wendell Holmes, has divided the lookers on at the grand show of Nature—the progress of the seasons—into three classes—the poets, who perceive the beauty of things; the naturalists, who collect curious facts in regard to the habits of birds, insects, and flowers, and the scientists, with their infinitely unreadable tables of statistics relating to temperature, storms, and other objects of study. To these I venture to add another class—the people who are interested in the utilities of nature. To all engaged in agricultural pursuits the changes of the seasons are of so much practical importance as to require to be viewed from a more serious standpoint, and perhaps the patient labor of a scientific investigation will yield more of real value than the curiosity of the naturalist or the inspiration of the poet.

The advent of spring is the result of a very complicated series of changes, depending primarily upon the position of the earth in its orbit, which is made manifest to us by the retrogression of winter, the increased temperature of the atmosphere and soil, the awakening of plant life, and the various movements of animals which are induced by migratory instincts. The sum total of impression received at this attractive period of the year is the effect of the concurrence of many events between which we seek to trace some correlation or to untangle the threads of natural law which gives unity to all the phenomena of nature. The endeavor to fix a date for an event so variable as the advent of spring presents great difficulties. The civil division of the year, in which spring comprises the months of March, April, and May, suggests that astronomically the date of the vernal equinox, March 21, may be considered the beginning of spring for the northern hemisphere. From the present point of view, however, this date, applying to the northern hemisphere as a whole, has no significance in the tropics or the polar regions, neither of which can be said strictly to have a spring. While the event is a general climatic one, it is also local in character, and is modified for any place by its latitude and geographical position, by altitude or proximity to the sea, and by many minor features of topography. Spring arrives earlier in a sheltered valley or on a southern declivity than on a bleak hillside exposed to the north wind. The successive movements of cold waves of ever diminishing force also show that the advance of spring is not like the steady progress of the crest of a flood wave, but fluctuates—now advancing, now retreating, always slowly gaining, so that summer becomes dominant almost imperceptibly.

Of the manifold changes following the retreat of somber winter, which shall be used as the criterion for the advent of spring? Many events have been proposed for this purpose, as the breaking up of ice in rivers and the reopening of navigation, the movements of animals, the earlier phases of the growth of vegetation, and those employed by the meteorologist, as the advance of an adopted isotherm of mean temperature, or others depending on some supposed relation between climate and the other phenomena mentioned. It may be interesting to discuss each of these briefly.

The first named—the breaking up of ice and resumption of navigation—will necessarily find only limited application in northern regions, where the rivers remain frozen throughout the winter. Anyone interested in studying the average dates of the reopening of navigation in the northern rivers and the Great Lakes will find ample material in the Monthly Weather Reviews. At many places the arrival of the first boat is an event of much importance. The average date for the reopening of the Hudson river at Albany is March 19, from records extending back to 1786. The average date for the opening of the Kennebec at Augusta, Me., is April 6. A general examination of data of this kind, however, will show that the dates so found are too early to represent the advent of spring. As our object is to secure data for a sufficiently large number of stations throughout the United States to enable the construction of a chart graphically illustrating the successive advance of spring, the use of this criterion is impossible for lack of material in the warmer regions of the South, where the rivers never freeze.

The movements of migratory birds or of hibernating animals afford a very unsatisfactory means of determining the approach of spring. A sufficiently large number of trustworthy observations is not available, and most of the movements recorded are not made for the reasons usually assumed. It is a common error to suppose that animals, by some unknown sense, are able to foresee weather changes, and this vitiates the scientific value of most of the observations recorded. Very often these migrations are simply brought about by the exhaustion of the food supply in a certain region. It is true that many animals possess a superior sense of smell, of sight, or of hearing, perhaps a finer sensitiveness to minute atmospheric disturbances, which man has lost by his artificial mode of life (the use of fire, clothing, and shelter) removing him, in a measure, from the direct influence of nature; but for this loss he is fully compensated by his ability to invent and use the delicate instruments of modern scientific research. The special faculty, seemingly possessed by many animals, of anticipating the seasons is not due to a superior knowledge of meteorology, but is the result of experience during past ages, transmitted from one generation to another by inheritance, and producing the fixed habits of life now observed.[a] Many curious observations in regard to the first appearance of the ground squirrel, the migration of swallows, the far-off song of wild geese hurrying northward, may be found in that old classic, White's Natural History of Selborne, which contains also a model naturalist's calendar for that locality.

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[a] American Meteorological Journal, May, 1887, Popular Errors in Meteorology, by Prof. Cleveland Abbe.

From the point of view of the naturalist, the ideal criterion of the advance of spring must be the awakening of plant life. Plants are fixed in their habitat, and are subjected to all the influences of their environment, and while the progress of growth is largely controlled by chemical and physical features of the soil, the chief factors must be temperature, moisture, and sunshine. Plants reflect perfectly the successive phases of the grand panorama of the seasons from the moment when the first warm breath persuades the crocus to push up its flowers through the snow. The determination of the commencement of the various phenoma of plant life, of the unfolding of the foliage and flower, the ripening of the fruit, and fall of the leaf, in their relation to the seasonal changes that take place, constitute the so-called phenological observations. Phenology is extremely important in the study of the geography of plants, and is of no less value for climatology, though meteorologists have rather neglected this attractive work. The large mass of material available must generally be sought in botanical works, and it is to be regretted that the memoir on the subject of phenology prepared by Prof. Cleveland Abbe in 1891 was not published by the Weather Bureau.

The difference in the behavior of different species of plants serves to give account of the gradual advance of spring. Thus the snowdrop, bloodroot, and claytonia herald the earliest touch of spring; peaches and cherries bloom early, and often suffer for their intrepidity; while oaks and walnuts are slow to respond to the influence of warm weather.[b] There are two ways of utilizing the material furnished by phenological observations. By comparing the dates of blossoming of the same species of plant at different places, the retardation of vegetative development with increasing latitude is brought out, with such variations as may be caused by topographical features. Using the island of Lesina in the Adriatic Sea (latitude 43° N.) as the starting point, it has been found that spring at Paris (latitude 48°) is retarded forty-three days, at Brussels (latitude 50°) fifty days, and at Christiania (latitude 60°) eighty-six days. In continental Russia the retardation is much greater, and while at Paris many spring plants are in full bloom vegetation on the Russian steppes, at the same latitude, is still deep in winter sleep.[c] Again, we may ascertain the places where spring plants blossom simultaneously, and a comparison of the latitudes will reveal the influence of climate. Thus, at New York, which is at the same latitude as Naples, plants blossom at the same time as at Marburg, Germany, 10° latitude farther north.[d]

The first attempt in this country to compare the seasons by the flowering of plants was made by Dr. Jacob Bigelow in a paper published in the Transactions of the American Academy in 1841.[e] The progress of the waves of warm air, as indicated by the flowering of the peach, was recorded for 1817 at the following places: Charleston, March 6 to 12; Richmond, March 23 to April 6; Baltimore, April 9; Philadelphia, April 15; New York, April 21 to 26; Boston, May 9; Albany, May 12, and Montreal May 12.

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[b] The Advent of Spring, M. W. Harrington, Harper's Magazine, May, 1894.

[c] Natural History of Plants, Kerner von Marilaun, vol. 1, p. 565.

[d] Ibid. p. 566.

[e] Works of Oliver Wendell Holmes, Riverside Edition, vol. VIII, p. 132.

Comprehensive statistics of this kind are available and would repay detailed investigation. I think, however, in phenological observations too exclusive attention is given to the effect of temperature on growth. The condition of the soil, which is the seat of complicated physical and chemical changes, is of the highest importance to the growth of vegetation, and it may be that frequently the permanent warmth of the soil has more to do with starting the flow of sap in spring than the temperature of the air, since in countries without a winter covering of snow the temperature of the soil is higher than that of the air above it throughout the year. The influence of moisture is also largely neglected. In tropical countries many plants undergo a period of rest during the dry season, which corresponds with our winter, and an increase in the amount of moisture at the beginning of the rainy season calls forth all the phenomena of a luxuriant spring. In addition, while many plants possess elaborate means of protection from excessive loss of moisture by transpiration, it is still doubtful whether any means of protection from changes of temperature have been discovered. A botanist can tell at a glance whether a plant occupied an arid or a humid region, but he can not say that it belonged to the flora of a cold or warm climate.[a]

The determination of spring by the successive advance of an adopted isothermal line is the method which naturally commends itself to the meteorologist, and is the only one possible for the purpose of a graphic representation. The endeavor is made at the same time to select an isotherm which has some distinct relation to the phenomena of plant growth. The only attempt of this kind with which I am acquainted was made by Prof. Mark W. Harrington, in Harper's Magazine for May, 1894. Professor Harrington accepted as the criterion the advance of an isothermal line of 43.8° F., and endeavored to establish a causal relation between the adopted temperature and the beginning of development in plants, in the following words:

> Botanists state that the temperature of 42.8° F. is that at which the protoplasmic contents of the vegetable cell find the limit of their activity. When the temperature falls below that point the protoplasm becomes inactive, though it is not dead until the fall is from several to many degrees lower, depending on the species of plant. When the temperature rises and reaches that point the protoplasm awakens, and as it passes above 42.8° F. the cells begin to grow and multiply. The advent of spring may be considered to take place at the advent of an isotherm 1° higher, or at 43.8° F.

This statement seems to me to be open to serious criticism, and the isothermal line adopted is really quite arbitrary and with very little relation to the phenomena it is supposed to mark. It can only be conceded that the rapid and agreeable change from the dull gray of the forests to a refreshing green does not occur much below that temperature, but otherwise it corresponds with no particular stage of vegetative growth.

Different stages of physiological activity in the protoplasm of plants probably occur from the lowest temperatures known up to several degrees above the boiling point of water. We consider here only the temperature minimum. Recent experiments by Dewar with liquid hydrogen, while not bearing strictly on this subject, may be mentioned for their intrinsic interest and the wonderful light they shed upon the problem of the origin of life upon the globe. The action of liquid hydrogen on certain bacteria was tested at a temperature of about

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[a] Pflanzen-Geographie, Dr. A. F. W. Schimper, 1898, pp. 40, 41.

—418° F., or within 41° of absolute zero, for twenty hours without any impairment of the vitality of the organisms.[a] Perfectly dried seeds and the spores of certain algæ have about equally great powers of resistance to destruction by low temperatures. I venture to express the opinion that no degree of cold whatever is able to cause the death of perfectly dry, so-called resting protoplasm, yet it must be presumed that some faint trace of physiological activity continues even at these low temperatures. In growing vegetable cells the activity of the protoplasm is manifested between far narrower limits. Thus, in *nitella syncarpa* the streaming movements of the protoplasm, the direct indication of active life, continue at a temperature of 26° F. There is experimental proof that assimilation continues in the evergreen leaves of pines at temperatures near and slightly below 32° F. The growth of many plants is very active at temperatures near freezing. The development of the inflorescence of the snowdrop (*galanthus nivalis*) takes place easily and quickly at a temperature not much above 32° F. It has been proved with regard to the earliest phase of growth, the germination of seeds, which certainly involves a rapid multiplication of cellular tissue, that not a few species are able to germinate at very low temperatures. The seeds of white mustard, of wheat and rye, and of wild violets germinate between 32° and 34° F.; of flax, onion, poppy, and beets between 34° and 41° F.; beans and sunflowers, 41° to 51° F., and, on the other hand, cucumbers and melons do not germinate until the temperature rises above 61° F.[b]

It appears, therefore, impossible to select a temperature which shall represent a sharply defined stage in the growth of vegetation. The selection of the 44° F. isotherm is also inadmissible for a latitude where daily mean temperatures above that degree occur for days in succession, even in midwinter, and this compelled Professor Harrington to deny the Gulf States the pleasures of spring. Examining the criterion further by the results obtained, the criticism may justly be made that for a larger portion of the country the dates given are far too early. The earliest line shown on Harrington's chart is that for February 1, which passes through Norfolk, Va., over western North Carolina, above all the Gulf States to El Paso, Tex., thence northward above San Francisco. Over practically the entire region called the cotton belt spring is supposed to begin before February 1. For North Carolina this date is certainly very inaccurate. While the normal mean temperature for the State at large for February is 43.3° F., yet the month is frequently our most severe winter month, and it is the only one during half a century in which temperatures below zero have been recorded as far south and east as Raleigh. Spring can hardly be said to begin at Memphis, Tenn., on February 1. Professor Harrington's line for April 1 passes through Philadelphia, Indianapolis, slightly north of Denver, Salt Lake City, then curves northward to Spokane, and leaves the continent at Olympia.

A more practical criterion of the advent of spring is certainly to be found in the average date of the last killing frost or occurrence of a minimum temperature of 32°, an event which has been determined with considerable accuracy for a large number of stations throughout the United States. A killing frost is defined as one which will cause the death of relatively hardy vegetation, including nearly all the plants of ordinary cultivation. It is well known that the young and tender vegetation of spring is easily destroyed by frost, and the important rôle played by the physical properties of water in the process are now well understood. Freezing depends on whether the affinity of the protoplasm for water is less than the molecular forces causing crystallization. If the affinity of the protoplasm for moisture is overcome, the water exudes from the cells into the intercellular spaces, where it crystallizes, and death results from the loss of water at a time when metabolic processes are at a minimum. From the point of view of agricultural interests the first and last killing frosts are events of much practical importance, which often exert a marked influence on the yield of crops. They determine, in fact, the limits of the growing period for most crops, and the immense damage often done by late frosts has led to strenuous efforts to secure means of protection. Consequently the last killing frost, as a natural event easily determined, with a distinctive influence on vegetation, may correctly be considered as marking the final passage of winter, the point of beginning of uninterrupted progress in the growth of vegetation—the advent of spring.

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[a] The Effect of Physical Agents on Bacterial Life, Dr. Allen Macfadyen, Popular Science Monthly, January, 1901.

[b] Natural History of Plants, Kerner.

The records of killing frost at 130 stations of the Weather Bureau were used in preparing the charts accompanying this paper.[a] Many facts of great interest appear in this connection. The earliest date recorded is January 20, at San Diego; since, however, the people of southern California claim perpetual summer for that delightful climate, we can hardly permit them to enjoy the pleasures of spring. By February 1 spring has commenced along the entire coast line of the Gulf of Mexico and over Florida, but its progress during February and March is rather slow. The line for April 1 starts from a point on the Atlantic coast some distance north of Norfolk, Va., passes southwest through eastern North Carolina, curves around the south end of the Alleghenies, passes through Nashville, Tenn., above Cairo, Ill., and thence takes a wide southward bend below the Rocky mountain region; in the extreme West it passes directly northward along the western edge of the Sierra Nevada Mountains, and leaves the United States north of Seattle, Wash. Thus spring prevails over the entire Pacific coast region and throughout the cotton belt by the beginning of April. The advent of spring occurs during April throughout the larger portion of the United States, including the Middle and North Atlantic States, the Ohio and central Mississippi valleys, the eastern and southern slopes of the Rocky mountain region and sheltered valleys in the West, and is deferred to May only along the northern border from Northfield, Vt., through the upper lake region, and over the two most elevated regions of the West, the Rockies from Denver to Helena. and the Sierra Nevada of eastern California and Oregon.

The change from winter to spring is of course profoundly modified by the larger topographical features of the country, as well as by the influence of position in regard to the prevailing course of storms. There is a marked trend northward of the lines both on the Atlantic and the Pacific coasts, so much more pronounced on the latter that spring has already commenced at Portland, Oreg., and Tacoma, Wash., before it reaches Norfolk, 10° of latitude farther south.

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[a] Data furnished by the central office. See Plates XXXIV and XXXV.

Plate XXXIV. Average date of last killing frost in the United States.

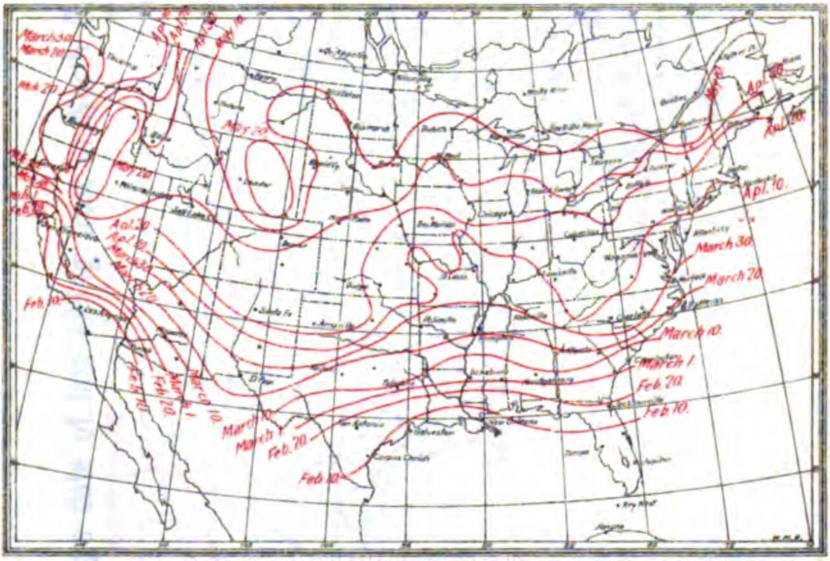
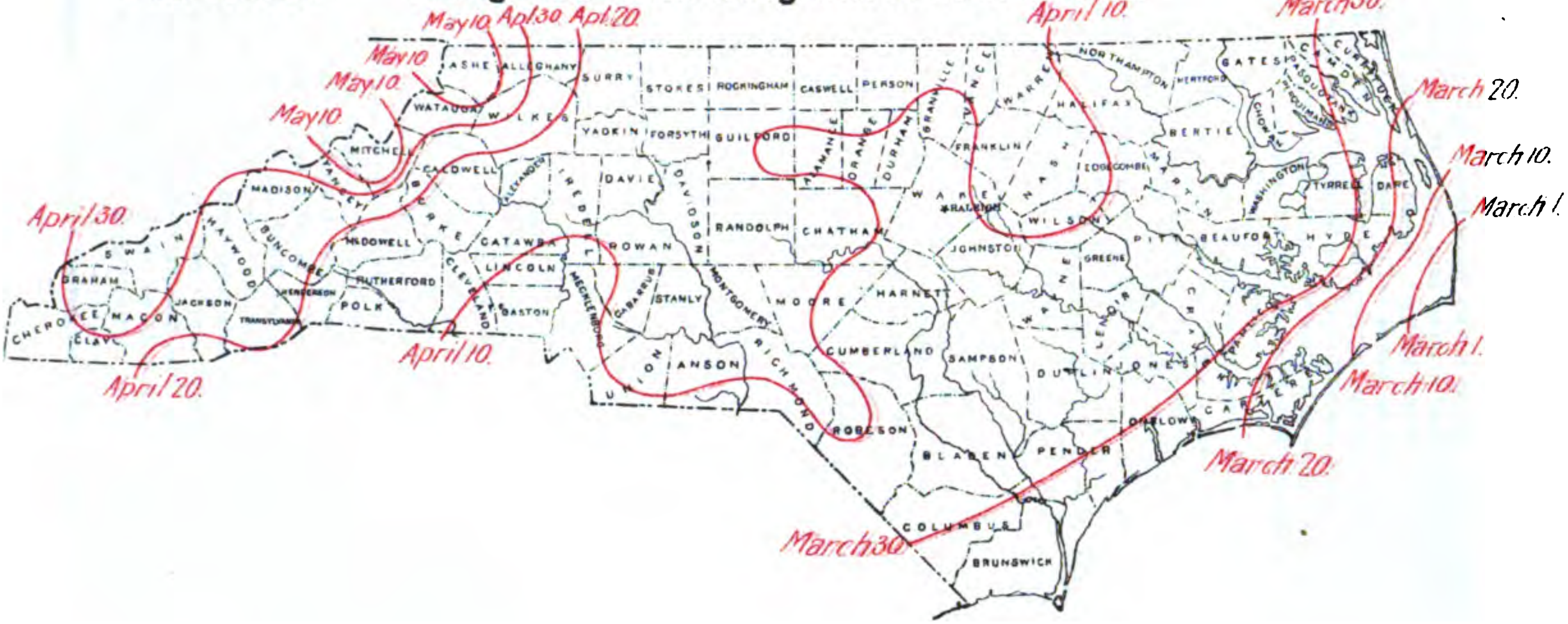


Plate XXXV. Average date of last killing frost in North Carolina.



There is also a moderate northward curve in the entire Mississippi valley as far north as St. Paul, and even a bend toward the northwest in the Lower Missouri basin. Spring occurs at Cairo before it begins at Charlotte, a hundred miles south, and at St. Paul before it reaches Detroit. This earlier advance of spring in the Mississippi Valley can hardly be attributed to the influence of the river itself, but must result from the fact that this section is open to the sweep of early southerly winds, caused by the successive development of areas of low pressure over the plateau region.

On the other hand, there are sharp southward bends of the lines of equal advent of spring over the Sierra Nevada and Rocky mountain regions, as well as over the lakes, the latter being farther extended southward by the influence of the Appalachian system. The retarding influence of the lakes is quite peculiar, as it falls chiefly on the eastern shores; in other words, spring advances in the lake region from west to east.[a] The retardation of spring in New England is partly to be attributed to the effect of elevation (White and Green mountains) but chiefly to the proximity of the frozen waters of the Gulf of St. Lawrence. Spring, however, is earlier on the coast of Maine than at any place in New York at the same latitude.

Attention may be invited to one more feature of special interest—the remarkable contrast in climatic conditions regarding the vernal season to be found in California and Oregon. The rapid advance of spring on the immediate coast from Los Angeles, February 6, to Seattle, March 31, has been referred to. Within little more than 100 miles in the vicinity of San Francisco, across the crest of the Sierra Nevada, is found the region of latest approach of spring in the United States. This comprises a portion of eastern California, western Nevada, and central Oregon, or the region between Carson City, Nev., and Baker City, Oreg., where spring is delayed beyond the middle of May, judging by the criterion here assumed. Over a considerable area of the extreme northwest, extending from Denver through Cheyenne and Lander, Wyo., to Helena, spring does not fully take possession until the middle of May.

From the nature of the case an investigation of the problem over more limited areas will yield details of greater interest. A similar chart has been prepared for North Carolina from the records of killing frost at 50 stations. The State is extremely diversified in topographical features; in its western region, poetically termed the "land of the sky," are found the highest mountains east of the Rockies, and its eastern extremity is thrust into the Atlantic beyond the normal trend of the coast line. On Smiths Island, near the mouth of the Cape Fear river, vegetation of semitropical nature flourishes. The time required for spring to obtain complete dominion over the State is over two months, or about the same as it requires to pass from northern Florida to central Michigan. The earliest date is February 28, at Hatteras, the latest May 10, at Blowing Rock, in the highest region of the Blue Ridge. The line for April 1 is 50 miles within the coast which it follows, and that for May 1 is very irregular and is chiefly governed by the topographical features of the Great Smoky mountains. Thus, over a large portion of North Carolina spring arrives during April. The popular saying in this State is that the leaves always attain their full growth by May 10, then summer holds undisputed sway.

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[a] Similar facts were brought out in Harrington's paper, already referred to.

LIGHTNING RECORDERS AND THEIR UTILITY IN FORECASTING THUNDERSTORMS.

By Mr. James Kenealy, *Cleveland, Ohio.*

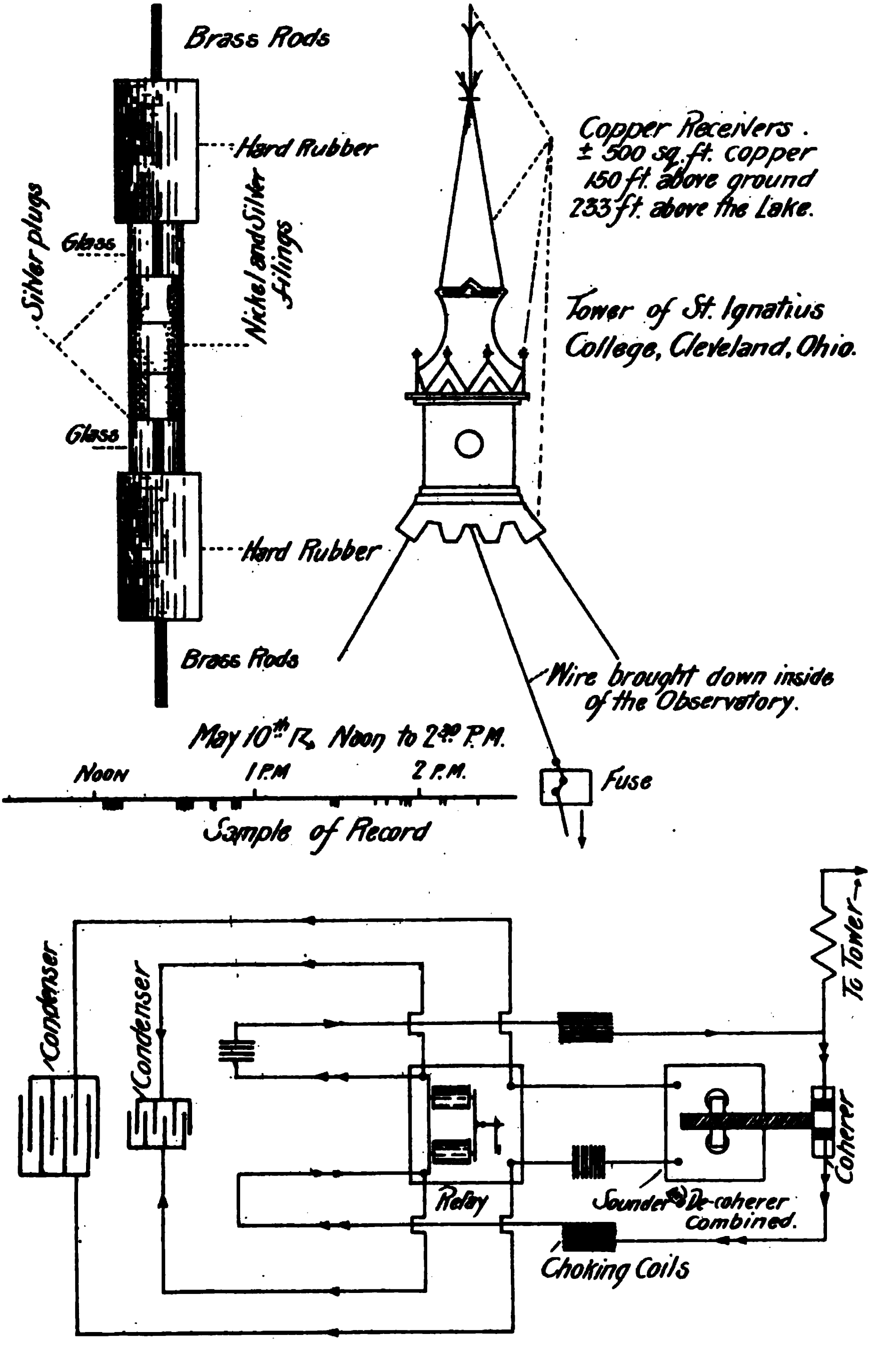
[Read by title.]

In the investigation and the study of electricity, during the past few years, particular attention has been given to the properties of electro-magnetic, or Hertzian, waves. The experiments made with the view of applying this form of electrical energy to practical uses have had chiefly for their object the transmission of signals by some one of the many systems of wireless telegraphy. I wish to invite attention to another application which I believe will be of especial interest to meteorologists.

Three years ago a well-known maker of scientific instruments—Ducrete, of Paris—noticed that an instrument which he had constructed for the purpose of sending signals by a certain system of wireless telegraphy responded to flashes of lightning. Later—about a year ago—Boggio Lera, of Sicily, succeeded in obtaining records of lightning flashes, by using a receiver constructed according to the plans of Marconi, and since that time Professor Rizzio and Dr. Pochettino have made use of similar lightning recorders at certain European stations, where the efficacy of the shooting of cannon against hailstorms was being tested—the stations of Casala and Colegniano. The exact construction of these recorders is unknown to the writer, but it is probable that the instruments are described in "Comptes Rendus, CXXXI, No. 22, November 26, 1900."

In the city of Cleveland, about a mile in a SSW. direction from the office of the United States Weather Bureau, there is a Jesuit college, of which the scientific department and observatory are in charge of the Rev. Father F. L. Odenbach. A few months ago it occurred to Father Odenbach that he could probably obtain records of distant thunderstorms by the use of the copper-capped tower of the college as a collector. This he has succeeded in doing. The instrument he employs includes what is known as the Lodge coherer, an ordinary relay of 50 ohms, and a sounder. For the benefit of those who may be unacquainted with the construction and nature of a coherer, I will state that it consists essentially of a break in a circuit, the break being filled in with a metallic powder that offers an infinite resistance to a voltaic current, but under the influence of lightning flashes this resistance breaks down. In explaining the action of the coherer, Father Odenbach states that its high initial resistance is due to a film on the surface of the metallic particles, and that the reduction of resistance by electro-magnetic waves is due to some kind of electrolytic transfer of ions across this film, resulting eventually in a deposit of ions in the form of bridges over the gaps, whereby the particles are connected with one another and form a conductor. This explanation, he states, is in accordance with the views of such authorities as Lodge, Arons, Slaby, and Van Gulik. Within the circuit is placed a relay, and, at the least breakdown of the resistance, the sounder, which is connected with a secondary battery, is shunted in by the relay, gives the signal, and decoheres the powder. The decohering of the powder is caused in this instrument by the tapping of the lever of the sounder, which at the same time moves the pen that makes the record.

Plate XXXVI. Diagram of Lightning Recorder and Connections.



Diagrams showing the plan of the lightning recorder, including the coherer and the copper collector on the tower, together with a sample of the record, are herewith shown. (See Pl. XXXVI and fig. 5.)

The instrument is yet in an experimental and imperfect form, but it is expected that an improved coherer will soon be substituted for the present one, which, however, has given fairly satisfactory results.

A set of very interesting records of 32 thunderstorms has been obtained this season since June 1. Data obtained therefrom have been tabulated, and are given below, showing the dates and times of first register of lightning flash and the times when the first thunder was heard, respectively, at the college and the Weather Bureau station. From these data it appears that in many cases lightning flashes were registered one to nine hours in advance of the first thunder heard in the vicinity of the college or the station of the Weather Bureau.

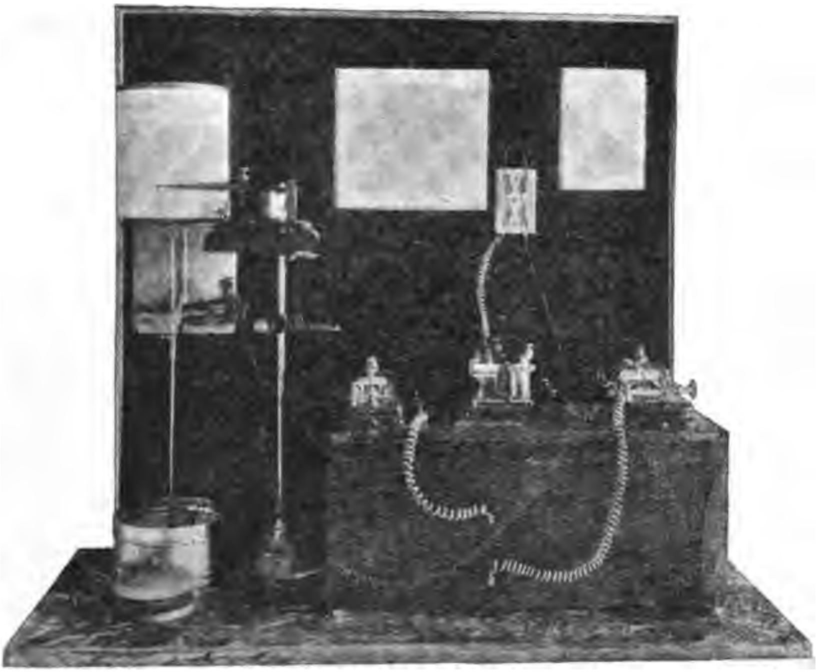


FIG. 5.—Experimental form of lightning recorder.

Date.	First register.	Thunder first heard in vicinity of—	
		College.	Weather Bureau.
June 1	2.45 p. m.	5.40 p. m	5.40 p. m.
2	12.20 a. m	3.10 a. m	3.48 a. m.
5	4.05 p. m	5 p. m	None.
8	1.30 p. m	None	Do.
9	2.55 p. m	do	Do.
10	6 a. m	7 p. m., over lake	Do.
11	12.50 a. m	4 a. m	2 a. m.
12	11 p. m	12.45 a. m	1.15 a. m.
13	12.10 p. m	1 p. m	12.47 p. m.
14	11.10 a. m	None	None.
15	11.55 a. m	12 noon (?)	Do.
17	12.10 p. m	1 p. m	12.47 p. m.

Date.	First register.	Thunder first heard in vicinity of—	
		College.	Weather Bureau.
June 19	2 a. m	9 p. m	9.30 p. m.
19	11.45 a. m		
19	9.20 p. m		
20	12.30 p. m	1.15 p. m	2.15 p. m.
20		9 p. m	12.40 p. m.
21	12.05 a. m	4 p. m	3.42 p. m.
22	7.05 p. m	7.15 p. m	7.25 p. m.
24	6 p. m	None	11.43 p. m.
25	1.15 p. m	do	12.10 a. m.
July 1	12.10 a. m	do	None.
2	8.10 a. m	do	(a)
3	6.05 p. m	do	None.
4	9.35 a. m	7.45 p. m	2.15 p. m,
4	7.15 p. m		6.53 p. m.
5	5.35 p. m	11.50 p. m	5.54 p. m.
		10.15 p. m	
11	12.30 a. m	12.50 a. m	12.55 a. m.
15	11.00 a. m	5 p. m	5.42 p. m.
16	3.15 p. m	None	3.27 p. m.
17	3.30 p. m	do	(a)
21	6.25 p. m	do	(a)
24	4.05 p. m	do	Early morning.
26	2.25 a. m	3.30 a. m	2.10 a. m.
26	11.15 p. m	3.55 a. m. of 27th	11.50 p. m.
27	12.30 p. m	12.30 p. m	12.50 p. m.
27	3 p. m		5.30 p. m.
30	11.05 a. m	None	None.
Aug. 5	5.20 p. m	do	Do.
14	8 p. m	1 a. m. of 15th	Do.
17	2.05 p. m	3 p. m	Do.
18	2 p. m	3 p. m	Do.
19	1 p. m	4 p. m	Do.
20	10.15 a. m	1 p. m	Do.

[a] Distant lightning only.

It can scarcely be doubted that results of great value will be obtained from the comparison and study of such records as these in connection with collated reports of thunderstorms in the surrounding region within a radius, say, of 100 miles. The problem of determining the exact locality in which any of these silent and invisible forces has its origin must be classed with the many other problems concerning whose solution expectation is now on tiptoe. It would seem that under certain conditions of atmospheric pressure, temperature, and humidity the lightning recorder should furnish valuable aid to the forecaster, more especially during the periods when the daily weather map indicates a possibility of the formation of thunderstorms in the region immediately west or south of the station, while no report of the actual occurrence of a thunderstorm has been received from any station in the section.

THE CAREER THE WEATHER BUREAU SERVICE OFFERS TO YOUNG MEN.

By Mr. Roscoe Nunn, *Nashville, Tenn.*

[Read by title.]

The Weather Bureau service appeals to men whose aspirations tend more toward a life of study and intellectual employment than to financial achievements, though what might be termed "business judgment" is certainly an important qualification for the higher positions in the service. It appeals to men who are content with a modest living, but who are desirous of occupying useful places in society. My object in writing this paper is not to try to induce outsiders to seek positions in the Weather Bureau, but to address especially the young men who are my contemporary observers.

In choosing his life work, a young man of worthy ambition and true ideals will ask these questions concerning any calling that may be suggested: (1) Is it honorable? (2) Is it worthy of one's best efforts? And then he will ask: (3) Is there opportunity for advancement and does it promise to reward with a fair degree of success the devotion of one of such ability as I may have?

If the first question suggested should be asked concerning the Weather Bureau service, the affirmative answer could be given very readily. Certainly no calling can be more honorable than one which seeks to develop a science and make practical use of it for the benefit of all mankind; a science that has so far passed the experimental stage that the National Government has for over thirty years maintained a meteorological service for the benefit of its citizens, while at this time all the civilized countries of the world have similar services. Employment in any department of our Government is certainly honorable, but a position in one of the most important scientific bureaus is particularly desirable; so that, in this case, the question, "Is it honorable?" is satisfactorily disposed of with a moment's thought. The second question, "Is it worthy of one's best efforts?" is also easy to answer. It should be sufficient to recall the names of some of the distinguished men—scholars and scientists of world-renowned ability—who have devoted their great talents to the advancement of meteorology—Maury, Redfield, Espy, Loomis, Ferrell, Scott, Hann, Abbe. If these men found it worthy of their earnest labor, surely the average young man need not have any misgivings as to the worthiness of the calling. But the actual, material results of the Weather Bureau service—the great benefits accruing to commerce, agriculture, and the general welfare—show every day that the men who labor to bring about such results are engaged in a work of a high order.

The Weather Bureau is now so thoroughly established and its machinery so well organized that one entering the service has a very desirable career open to him. It offers a promising field for the young man of scientific tastes and training, a field for hard work and study, a field of great usefulness; and to those who shall bring the powers of invention, thought, and industry to cultivate and discover the vast riches of this field there are high honors and rewards more satisfying than gold.

As to financial success in the Weather Bureau, it is limited, as, of course, success in any salaried position must be; also, rewards are not so great as in some other callings. But to one of average ability and industry a fair salary is insured during satisfactory service, while the higher positions in the service pay more than the average professional or business man earns. It must be admitted, however, that opportunities for advancement are not so great—possibly not so frequent—as in some of the larger departments of the Government service, and certainly in many of the large private corporations there are opportunities for men of ability that far exceed any possibilities in the Weather Bureau.

It is a comforting assurance that in the Weather Bureau one is advanced according to his merits. With the assurance of permanence of employment and promotion for merit, one can contentedly devote all his energies to the improvement of his talents and the upbuilding of the service.

One is required to stand a fair examination for entrance as observer; if one receives an appointment, it is probationary—one is assigned to a station on trial for six months. It is the duty of the official in charge of that station to make the strictest monthly reports on such probationary appointee as to his fitness to continue in the service, and unless the reports are satisfactory to the chief of the bureau the probationer does not receive a permanent appointment. There could hardly be a better system for keeping unfit men out of the service.

Of the several progressive steps that have recently been taken, I think none will prove more helpful to the service than the inauguration of courses of study and examinations for promotion. This step undoubtedly meets with the hearty approval of all those who are really willing to abide by the merit system and who are truly desirous of improvement in the personnel and efficiency of the corps. These examinations are good tests not only of the mental ability of the employee, but of his energy and industry; if one is unwilling to prepare for these examinations he is likely to be unwilling to do many other things that reasonably might be required of him in his daily work. The pursuit of these studies is also an excellent thing to train one to habits of study—and students we certainly must be if we expect to go forward. Such requirements as these are encouraging to the young men of ambition, energy, and ability, for they help to keep the service purged of the indolent and incompetent and make room for the meritorious. Every such progressive movement raises the service to a higher plane and inspires right-thinking young men of the lower grades to increased endeavor and higher hopes of honorable and successful careers.

Observers on station have exceptional advantages for independent effort in the way of study and investigation. One can find time for study, and the nature of an observer's duties are such as constantly to encourage him to endeavor to enlarge his fund of general information and particularly his knowledge of the sciences.

To some the field of action in this service may seem limited or barren, but this is certainly not true. The longer I remain in the service the broader and richer the field appears. There are opportunities on every hand for extending the work and accomplishing good. The public has not yet learned in how many ways we can be useful, nor have we ourselves; but, as the varied character of our work becomes better known, the public call on us oftener and oftener to fulfill our mission as public servants, and, as we study the needs of the various industries of our land in their relation to climate and weather conditions, we constantly find new ways of increasing our usefulness. It is being discovered that the Weather Bureau, with its meteorological records, climatological data, daily forecasts, special warnings, climate and crop service, etc., can be of benefit to almost every kind of commercial and agricultural industry.

It is the duty of the Weather Bureau official to assist the public to an understanding of the value of the service and a proper appreciation of it. Let it be known that we have something of value to give and that we are always anxious to comply with any reasonable request.

I am of the opinion that the greatest immediate improvement of service that could be accomplished would be the training of the Weather Bureau officials to the highest point of alertness and expertness in the use of the knowledge and machinery that we already have. Discoveries of new and important laws may be near or they may be distant; but while ever looking to this end let us not fail to recognize the importance of the quickening of the working corps and the perfecting of systems already in use. To the greatest extent this kind of improvement depends on the individuals of the service, and the young men who hope to rise to higher places should realize this and profit by putting the suggestion into practice. The successful Weather Bureau official must think seriously of his duties; must seek out new duties; must train himself to be thorough, exact, expert in all. He must broaden his conception of the Weather Bureau work by study, by investigating the needs of his community in relation to the Weather Bureau, and seeking to make the service of increased value. He must not be satisfied with performing merely the routine duties imposed upon him, but must be on the alert to use every opportunity to broaden the scope of his work.

I should be glad to see every employee of the Weather Bureau, from the highest to the lowest, thoroughly imbued with the idea that our work is of the highest class; that the field of usefulness is very large, and much of it yet unexplored; that every individual is called upon to devote his talents and energies to the advancement of the science of meteorology and the improvement of the service; that our calling is worthy of our devotion; and also let us feel confident that we shall receive full credit and reward for every good thing that we accomplish.

SECTION 2—EDUCATIONAL.

ADDRESS OF THE CHAIRMAN, DR. W. F. R. PHILLIPS, OF WASHINGTON, D. C.

It is my privilege to lay before you the program of this section. It is not my purpose to impose upon your patience anything quite as formidable as an address, the program to the contrary notwithstanding. The papers to be read in this section are apparently divisible into two general classes—one dealing with meteorology as a branch of popular education and the other dealing with meteorology, or, as it is more commonly called, climate, as a biological factor. Of climate as a factor in biological study, one has but to consult a bibliographic index to see how immense is the mass of literature upon this subject and how early in history it became one of absorbing interest. Tell a man of some unfamiliar country, and the first questions will be about its climate—is it healthful, is it productive, what grows there, and what will grow there? These are the subjects upon which interest first centers, all because by long experience man knows that in some way—vague, often apparently contradictory—that which is called climate controls these things. It is our hope to find out ultimately how this control is exercised. In by far the greater number of existing studies of the general problem of climatic control of organic life, the method of investigation that has been followed is that of comparing numerically the different classes of events studied and drawing conclusions from arithmetical correspondences. Inasmuch as this method does not of itself impose any limitations upon the facts compared, except that of susceptibility of being counted, its resulting correspondences or discrepancies can be construed at most only as fortuitous coincidences or accidental contradictions. This method is, however, within certain limits useful, especially as a preliminary process. The scientific method of investigation is that of direct experimentation. Here the facts compared are the apparent results of the energy of one system on that of a different system, and the summation of such results represents numerically the probability of casual relationship.

The laboratory is the present arena of this method. Of hypotheses there are many; of experiments there are few.

Meteorology as a subject of popular education is of so recent appearance that its position in the curriculum of general knowledge is not yet well defined nor are its limitations therein established. What has been accomplished toward giving it a status in the schools and before the public of our country is largely due to the fostering attitude of the Weather Bureau. Considered simply as a mental discipline, meteorology is the equal of many of the other didactic subjects, the teaching of which is justified on this basis. As a study itself it is interesting and even entertaining. The utilitarian applications of meteorology are obvious and need no recital, for there are few occupations to which a foreknowledge of coming weather is not of value. Meteorology has much to commend it as a subject of popular interest. There is, however, in connection with the popular study of meteorology, alike with that of the other sciences, a difficult problem to solve, namely, that of giving to persons that do not contemplate being specialists a knowledge of the science that shall be useful and not mischievous. This problem demands, and I bespeak for it, your serious consideration.

UNDER EXISTING CONDITIONS OF STATION WORK, IS IT PRACTICABLE TO REQUIRE ASSISTANTS TO PURSUE A SYSTEMATIC COURSE OF METEOROLOGICAL STUDY.

By Mr. G. N. Salisbury, *Seattle, Wash.*

I feel that it is necessary to preface my paper with the statement that its contents are neither so broad nor so deep as this voluminous title would indicate. Probably the subject might be better treated by a professional educator or some one who has had experience in educational matters. I hope the experts here present will not be uncharitable. The paper may appear trivial to them; it is not intended for them, but is intended to voice the views of the plodders in the service—the assistants on station and the young men of the service. My desire is always to champion the cause of the young men in the service, and my hope is that they may enjoy the benefits that I in my early days failed to enjoy.

The employees of the Weather Bureau, particularly the officials on station, come before the public in many ways, such as in answering requests for information, in newspaper interviews, in their section publications, and in lectures to educational institutions and societies. The desirability of a broad general education, to which is added a thorough knowledge of meteorology and its kindred sciences, is at once apparent.

The central office has recognized this desirability, study has been encouraged, and certain facilities have been provided for the prosecution of such study as will tend to keep the observer on station in touch with his work. Yet it must be acknowledged that at the greater number of stations the opportunities are very limited, both as to time and facilities, and the obstacles in the way of successful systematic study are difficult to surmount.

First of all, there is no school of instruction for the probationary appointee, who comes directly to the station to acquire practical knowledge of his duties and to study meteorology as he has opportunity. This often seems to impose a hardship upon the official in charge, increasing his care and responsibility without lessening the burdens of the station for the time. Yet it may be questioned whether a special training school would have advantages over the present method. According to the experience and recollection of the writer, the graduate from the six months' course at Fort Myer (the quondam training school of our service when under military control) generally appeared at station a novice, no better fitted for his practical duties than the probationary appointee now is on his assignment. Six months were thus in a great measure wasted, unless we except the supposed benefit of discipline. Some have maintained that it was the "Myer training" that so firmly implanted the conservatism of method and the "staying power" that so many of our good old officials are remarkable for.

It is probable that if a training school were established now it would be much more practical, more directly fitted for its purposes, and in any case free from the objections that characterized the former institution at Fort Myer.

Since the civil service has been extended to include the station force, new appointees are immediately assigned to station duty. In some cases these men are quite liberally educated; in others they have little more education than is necessary to pass the civil service entrance examination. The combined result is a second obstacle to systematic study. We have in the station force an unhomogeneous body—men with varied attainments. (1) Some who on entry into the service were of liberal education and have since extended it; (2) some who at first had limited education, but have since improved it, or at least have become well-informed and skillful in their practical work; and (3) some who are of limited education, but are anxious to improve. Nor should the fact be lost sight of that there are in the Bureau a number of excellent officials who have given many years to the service who in the ordinary course of events must soon begin to feel the infirmities of declining years. From them there can not be expected as much in work and study as of the young and vigorous, yet the practical knowledge gained by years of experience gives them a value in the service not to be attained at once or for several years by the newer men.

Now, the question under consideration becomes: How, without losing sight of our public duties, can the systematic study of meteorology and kindred sciences be pursued on station and what course is best adapted for such a diversified body of men? That such study will improve the power for usefulness of the officials and increase their interest is almost incontrovertible and need not be discussed. All have the desire to improve—the desirability is self-evident—and yet several obstacles to any uniform scheme present themselves. Most important of all, the main purposes of the Bureau, the daily practical service of the public, must not in any manner be neglected.

It would seem, at first thought, that any time taken for study from the regular hours of duty might be considered contrary to the principle which demands the highest usefulness to the public. It is essential, to be sure, that the daily routine be gone through with, that the records be kept up, and that the information at the disposal of the office be given the widest practicable dissemination, but much of the distribution can always be done by messengers and more economically by mail. It seems unnecessary that every member of the force should be constantly engaged in the routine of clerical work. Much better service can in many cases be given if a reasonable time is taken for reflection and study. Some might urge that the Government can not be justly called upon to educate its employees; that they should be sufficiently educated beforehand. There are three answers to this: (1) The individual of high educational attainments, if otherwise well fitted, can usually command a higher salary elsewhere than the Government usually pays. It is, therefore, more economical for the Government to employ men of but fair education at very moderate salaries and gradually educate them as required, increasing their salaries as they become more and more useful. (2) There are few, if any, facilities for acquiring on the outside the special education and training needed by Weather Bureau officials. (3) Other departments of the Government do educate their employees in the lines of work peculiar to their employment or service.

It is self-evident that the better informed the official is, other things being equal, the better work he can do for the public. Untrained persons, under proper direction, can do much of the routine, but it is always necessary that there shall be a force in training, preparing for higher work, as exigency may require. Observers are not mere clerks whose duties are to drudge a specified number of hours, but officials who, with discretionary power, often render higher service. The highest public utility is, I think, the keynote to the situation, and is the justification for spending a small portion of office hours in a regular course of study.

The study, to be effective, should be regular and systematic, not desultory. Many an official has attempted, as he could snatch the time, to read the various works on meteorology and cognate sciences in his station library, but duties would intervene, distractions would occur, and perhaps the study be finally abandoned in despair. But above all things else the course should be regular. It should present the latest developments in meteorology, and should be so articulated with the current work as to explain and develop it.

In no other way can the study be so well prosecuted on station as under the direction of the central office. In that office are centralized the results of series of investigations, from the earliest to the latest; there new investigations are constantly being undertaken; there, collected in the Weather Bureau library, is all that has been published in this country and the most worthy publications of other countries upon meteorology and cognate sciences. Translators of French, German, Spanish, and the other languages are there available, by whose aid the newest and best that is in the works of European writers can be culled and collated for the benefit of our Bureau. There, officials of long experience, who know how to select what is most valuable to the student, and separate the essential from the unessential, can weave such select material into a course of instruction which would embody what is valuable and progressive of their own studies and investigations, as well as those of advanced scientists in foreign countries. Unless the reading of the observer-student is directed by competent persons, he will inevitably waste much time and energy in absorbing what is valueless to him.

I should consider it advisable, after the officials have read the books now supplied their station libraries, with the addition of a good work upon topography—especially the topography of the United States—and perhaps some other works that might appear desirable, that a course of lectures upon atmospheric dynamics should be provided. This course of lectures should be extended to include other topics of interest and importance, particularly the relation of plant growth to its meteorologic environment. In meteorology it would be well to develop fully the problems that are most intimately associated with the work of forecasting. These lectures should also consider the general principles of climatology, the dominating idea being always to give as complete an exposition of the subject of weather processes, as full a knowledge of climatology, and as varied and useful a familiarity with cognate science as time and facilities will permit.

METEOROLOGY IN THE PUBLIC SCHOOLS—HOW MUCH SHOULD BE ATTEMPTED—METHODS OF TEACHING.

By Mr. F. P. Chaffee, *Montgomery, Ala.*

In my opinion meteorology should be taught in the public schools, for, while the higher institutions of learning may be as the nerve centers of the great system on which the political, commercial, and scientific welfare of the country largely depends, our very complete public-school system more nearly reaches the entire mass of the people. It is, as it were, the great artery from which the intellectual and commercial force of the country is drawn.

In a great many of the common schools, elementary human physiology, natural philosophy, and chemistry are taught. These studies to a certain extent interest the student in the temperature, weight, and humidity of the air, yet it would seem that a more intimate study of meteorology could be made interesting, instructive, and beneficial. In fact, were it not that the science of meteorology is comparatively of such recent origin, we might wonder at so little attention being devoted to the study of the air in which we live and on which we depend for all that makes life pleasant.

Assuming that meteorology should be taught in the public schools, the next question is, How should it be taught and to what extent?

While it is not necessary or desirable to disturb the progress which this science is making in the higher institutions of learning, it would be well in the meantime to begin at the bottom. Quite a proportion of the students in the public schools, particularly the males, are obliged to leave school after passing through the fifth or sixth grades, while a still larger proportion have to seek employment before passing through the high schools. Now, it is toward this class, the great mass of students who go to make up the commercial brawn of our country, to whom the practical meteorology of the Weather Bureau would be of advantage, that attention should be directed.

It is a fact, one which will be recognized by any experienced official here present, that persons who visit the Weather Bureau offices, and who have the work of the Bureau and its problems explained to them, become more interested in the Bureau, pay more attention to its bulletins, and make greater use of the information in their vocations. So, for this utilitarian reason, if for no other, a familiarity with the work of the Bureau, which would be engendered by having the study of meteorology taken up in the public schools, would give great returns for the efforts incident to properly starting such a work. All that is needed is a start, and, like many other lines of study the advantages of which were once doubted, meteorology will take care of itself.

This is a practical age. So much has to be crowded into our short lives that each one of us can not afford to learn entirely by personal experience; indeed, to do so would be a wasteful use of time and energy. To keep abreast of the times, we must profit by the teachings of those who have the experience which the ordinary layman has not the time to gain. Now, the Bureau has a corps of experienced workers, to many of whom the study of meteorology in its current phase has been a life work. These men, well distributed over the country, should each be a center from which to stimulate an interest in the study of meteorology in the public schools.

It is no difficult task to interest both teachers and pupils in some of the simple problems of meteorology, which to us, by constant association, may seem of but little general interest.

First, the matter should be properly presented to the heads of public instruction—the county superintendents of public schools, or, as termed in other portions of the country, the county commissioners. They should be made to understand that the nearest Weather Bureau official is willing to appear before the teachers' institutes to outline this work and to visit the various schools for a similar purpose. Also, that both teachers and pupils will be cordially welcomed at the nearby Weather Bureau station, where the work and aims of the Bureau can be better explained. The teachers should be shown the advantage of bringing the subject before their pupils. In a conversational way at first, by inviting their attention to any unusual weather changes, and the causes of these changes, as shown by the weather maps and bulletins. Then in the schoolroom, with an ordinary thermometer, a tin pail, 5 cents' worth of ice, and a handful of salt, some very interesting experiments can be conducted, showing the formation of dew and frost. Later, by means of a suitable glass tube, sealed at one end, a tumbler, and some mercury, the principle of the barometer can be explained, while, with the ordinary wet and dry bulb thermometers, the study of atmospheric moisture can be taken up. With even such simple apparatus, and a blackboard on which to illustrate the effect of altitude on the barometer, the air movements, the wind systems, etc., it is surprising how little is required to get a school interested in the subject. Later on, the study may be taken up in its more advanced form, but we must begin at the bottom to lay the foundation on which we desire to work.

Unfortunately, the science of meteorology has not as yet developed to such an extent that we have many absolute laws which can be given to the student; but the science has at least reached a stage where it can give some basic facts, which should be more generally understood by the public.

In many of the primary schools very attractive lessons in zoology, botany, and kindred sciences are contained in a series of books on nature studies, under such titles as "Mr. and Mrs. Crab," giving, in the most simple language, the habits of the crabs, how they feed, how they shed their shells, and how they live. Some treat of birds and their peculiarities and others treat of the germination and growth of plants. Each of these books contains interesting information. Now, it would seem that books in similar simple language on meteorological subjects under such titles as, say, "The story of a raindrop" or "The voyage of a cloud," etc., could be made to convey just the information we desire to impart. Even though no eminent meteorologist may develop among the students, still the work will not be wasted; and who knows but the seed sown may bear fruit much greater than anticipated?

The many books on scientific subjects, written in popular style, which have appeared in recent years have done more to stimulate a general interest in the applied sciences than all the purely technical works ever written. The scientist has in reality, in coming down to meet the general craving for truth, raised a popular desire for investigation hitherto unknown.

I think the Bureau would certainly not be going outside of its legitimate work to encourage the preparation and introduction of a series of books on meteorology for use in graded schools. In the meantime good work can be done in promoting an interest in meteorology by a more determined personal effort on the part of the various officials of the Bureau to bring the subject before the public schools whenever opportunity offers.

DISCUSSION.

Mr. S. M. **BLANDFORD** (Boise, Idaho). The introduction or the extension of meteorology in the school has a primary and a secondary object. The primary object is to reach the student directly and to give him a true conception of a science that may be useful to him in the ordinary affairs of life. The secondary object is to reach the parent, who has undoubtedly formed opinions regarding the weather and its laws which may or may not be in accord with the best information on the subject. A cross-questioning of the parent by his son will accomplish indirectly more toward changing the parent's impressions, if erroneous, than a great deal of direct argument by persons outside the family.

Fifteen years ago there was practically no thought given to the subject. To the best of my knowledge meteorology was first taught in a very crude way as one of the subjects forming a part of physical geography. At first meteorology was barely mentioned. At the present day thirty to forty pages of the average school physiography are devoted to the subject, and it is presented in such a style that the student secures a fairly accurate idea concerning its elementary principles.

A Weather Bureau official before lecturing to school classes should first inform himself as to the extent of instruction given in the school; otherwise he will be surprised to learn, occasionally to his discomfort, that some of the scholars comprehend the subject almost as fully as the lecturer himself.

A volume not too elementary, but more elementary than Davis' work, would meet the needs of the students of the high schools and academies and be of material service to the teachers. Could not the Weather Bureau undertake the preparation of such a work?

Mr. G. R. **OBERHOLZER** (Charlotte, N. C.). I do not think that meteorology is very well treated in school text-books, especially the physical geographies. In fact, the average physical geography seems rather to treat the natural sciences as a collection of curios than to attempt to teach natural laws. Text-books are deficient in this respect, and the reason is that people wish to have that kind of books, and the makers will continue to print the kind people will buy. I think the way to introduce meteorology into the schools is through the teachers. The extent to which the natural sciences are taught in the public schools is gratifying; the best educators are emphasizing the subject and making more and more of it. I do not think meteorology has the standing among the natural sciences that it should have. It offers to the teacher opportunities for instilling into the mind of the child truths regarding things that are all around it, and could be used to great advantage. I asked Mr. Thomas M. Balliet, superintendent of public schools of Springfield, Mass., about the teaching of meteorology, and received the reply following, which I wish to read to the convention, as it embodies the ideas of a practical educator:

> We have been trying to teach the elements of meteorology in our primary schools for some half dozen years, and I think we have at least partially succeeded. I may say in the first place that I believe all science teaching in the elementary

schools, and a good deal of it in the high schools, should aim primarily at explaining facts and phenomena in nature which all pupils can observe. There is more educational value in teaching one generalization in physics, for example, and showing the class fifty applications of it in nature and in mechanics, than there is in teaching the same class fifty generalizations, and making either no application or only one application of each principle. The latter is the plan followed in even our best high schools to-day. And the result is that the teaching of science does not open children's eyes to the world around them as much as we supposed laboratory work would necessarily do. To show a class of little children that heat expands solids, liquids, and gases, and then not to use the principle to explain phenomena in nature, is to miss by far the most important benefit which comes from a teaching of science. We may say in general that the best test of all school work is what it stimulates the pupil to do outside of school. With this preliminary point in view, I may say that there are a good many things in meteorology which are of scientific interest, but which can be omitted without detriment in teaching a class in elementary schools.

I believe it is possible to teach the subject to grammar-school pupils to an extent that will enable them to understand the ordinary weather conditions, and to be able to read intelligently a weather map. We have been emphasizing meteorology the seventh year of school. I think we shall push the work up into the eighth or the ninth year, where pupils are, on an average, about 15 years old. I may describe what we are teaching briefly, as follows:

First. In the upper primary and lower grammar grades, there is a record kept in each schoolroom, either on a manila-paper chart or on the blackboard, on which the children record from day to day the conditions of the weather. They also note the phases of the moon and other simple natural phenomena.

Second. In the fifth year of school they have simple experiments on heat and specific gravity, together with other topics in physics not so closely related to meteorology.

Third. In the seventh year of school they make a fair study of specific gravity and heat and the change in specific gravity by heat, and then make the application of it to air movements and movements of liquids. They make experiments with the bicycle pump to show that pressure heats air, and they also make experiments with the thermometer under the receiver of an air pump and notice that expansion cools air. In this way they learn the dynamic heating and cooling of the air. In connection with specific gravity they learn about air pressure and the weight of the atmosphere. There is a barometer in each grammar school. These principles are illustrated by applying them to vertical air currents, the formation of clouds, etc. Incidentally, winds like the chinook and the foehn are explained to illustrate the principles. With these preliminary steps carefully taken, the pupils are in a position to study the cyclonic conditions which determine the weather in these latitudes. The reasons why the air in a cyclone moves in a spiral, and why cyclones move from right to left in a northern hemisphere, and the reverse in the southern hemisphere, are beyond the comprehension of grammar-school pupils. These facts may be given them without an explanation. I am inclined to think that this is the only practicable way to treat them. Having given the spiral movement of air as a fact, the pupils are now ready to see the reasons for the cloud area and for the rain area, and why both areas do not extend equal distances from the center of the cyclone. They can now understand the direction of the wind in different parts of a cyclone, and therefore the change in the direction we have at any particular spot when a cyclone is passing over that spot. They can understand what is meant by a cold wave, and we find it is possible to make clear to them the air movement in an anticyclone and the weather conditions which it brings. We do not find it too difficult to teach many features of the West India cyclones, and I think most of our children in the upper grades comprehend the differences between these cyclones and those which pass over our country from west to east. Incidently we take up the subject of tornadoes and the ordinary thunder storms. I think most of our children understand the connection between these and cyclones. Such subjects as the trade winds and the monsoons can easily be taught in grammar schools.

I should think it a great mistake to attempt to teach the general circulation of the air in grammar schools, as is sometimes done by teachers that do not comprehend how difficult and complicated the subject really is. We have an exceptionally competent corps of teachers, but I do not believe that you would find half a dozen teachers in the city that could give any clear description of the general circulation of the air on the globe. It is therefore a mistake to begin the subject by attempting to describe this general circulation. This is usually done in books and in advanced instruction. I am inclined to think that it is the wrong place to begin.

Another mistake that is often made is to begin in a strictly inductive way the study of cyclones by observing the barometer readings and inferring from these the force and direction of the wind, and from this the temperature, etc. The barometer and the general subject of air pressure are too unfamiliar to young people's minds, even after they have had lessons on the subject, to make that the starting point and then learn by inference that which they find it very much more easy to learn by direct observation. I think this is the general mistake made in teaching meteorology in high schools.

As suggested above, the teaching ought to begin with the study of the direction of the wind, and, as a result, the temperature in different parts of the cyclone. And then the study of the barometric lines should be introduced by way of accounting for the force and direction of the wind.

The study of rainfall, or precipitation in general, is not difficult after the above series of lessons has been given. The subject of ocean currents can be effectively taught after the foregoing. If it is desirable to take up the general subject of climate, the pupils are now prepared to attack that with success.

The question as to how far it is wise to continue such work in grammar schools must practicably be determined by the qualifications of teachers, the maturity of the pupils, and the time which can be found in a course of study for the work.

The weather maps furnished by the Weather Bureau are absolutely indispensable to such work as we are attempting to do. The maps of the Boston weather bureau are in every grammar school and are extensively used.

Mr. H. M. **WATTS** (Philadelphia). I do not agree with those who would force too many subjects upon a child's attention. There is a great idea to-day of teaching sciences to children, but they really get very little out of it. To have meteorology taught in the public schools, I think, would only add another complicated subject to those already taught. Teach the children simple facts, but to introduce the system into the public schools I do not think worth while.

Mr. F. H. **CLARKE** (Scranton, Pa.). I want to go on record as against enlarging the curriculum of the public schools. My experience has taught me that the young men of to-day usually can not write a letter creditable either in composition or chirography. The trouble, I think, is that we are teaching a smattering of a great many things and nothing thoroughly. We are trying to teach pupils too much in too little time, a system that will never accomplish the greatest results.

Mr. T. B. **JENNINGS** (Topeka, Kans.). The best way to reach the children is through the teachers, just as Mr. Chaffee has said. You can reach the teachers through their institutes and associations. Get the teachers to bring the children to the office. Tell the children you have an instrument by which they *hear* the sunshine and *see* the wind blow. Now you have got those children interested. They stand by your triple register, and they do *hear* the sunshine and *see* the wind blow. Then there is another point: The Weather Bureau some few years ago sent out a cloud chart. I took some of them to our board of education, and they had them framed and hung in the schools. They got the children interested in keeping a record of the clouds each day, as indicated by those charts—that is, they compared the clouds seen in the sky with the pictures in the charts. They became interested in clouds, and could not see a cloud come up and pass over without comparing it with the chart. They got a very good idea of clouds from that. We must go to teachers' institutes and talk to them just as we would talk before a kindergarten class. The barometer tube, 36 inches long, is all right, but don't use a bucket for a cistern. Take a tumbler, have a cover fitted over it, insert the tube, and make it airtight. Then have two other holes, one through which you can apply a little suction pump, and another through which you can use a bicycle pump. By that means you can illustrate the falling and rising of the barometer as due to difference in the pressure of the air. They get the idea exactly. They know that when air is forced into that cistern the mercury is forced up the tube, and the reverse.

Mr. **Patrick Connor** moved that Mr. Jennings be appointed a committee to get up a pamphlet describing the construction of simple apparatus for distribution to pupils in the schools.

The **Chairman**. I think that the ingenuity of any teacher should enable him to devise such apparatus, and that Professor Marvin's circulars (Instrument Division circulars) give all the necessary suggestions.

Mr. **J. Warren Smith** (Columbus). I think the Bureau should issue a pamphlet of, say, 100 pages, for distribution to teachers as an elementary text-book on meteorology.

Mr. **A. E. Hackett** (Columbia, Mo.). Many of the teachers of the common schools come to the summer school at Columbia, Mo., and most of them come to the Weather Bureau office. I explain the use of the instruments to them, but they rarely carry away correct ideas of the value of the records or the uses made of them. I think some simple discussion of the phenomena of the weather, in a form that could be handed to them, would be very useful. Such a pamphlet they could take home for study.

METEOROLOGY IN COLLEGES; TO WHAT EXTENT IS IT TAUGHT AT PRESENT; SHOULD IT BE OFFERED AS AN UNDERGRADUATE OR AS A POSTGRADUATE COURSE?

By Mr. G. A. Loveland, *Lincoln, Nebr.*

More courses in meteorology have been offered in the colleges of the United States in the last year than ever before, and probably still more will be offered next year. Yet the instruction now given is almost insignificant compared with the commercial importance of the subject.

There are two principal reasons why meteorology has made such slow progress as an important branch of study in the colleges and universities. First, the teachers do not care to teach it. Secondly, its commercial value, or its value as an educational asset, has not been sufficiently realized. Let me explain these statements more fully. Those who decide what shall be taught in the colleges either have not introduced meteorology into the curriculum at all generally or have not encouraged students to take it when it has been offered, one reason being that often none of the faculty cared or had time to teach the subject. In fact, meteorology has not been developed by school men; that is, the professional teacher in the experimental laboratory, studying the science from a love of it, using the subject as a culture study, and imparting his enthusiasm for it to the students with whom he comes in touch. It has rather been developed by a few scholarly men at the demand of commercial interests, and therefore from a utilitarian rather than a scientific standpoint. It has been necessary to render an equivalent in practical money-saving results to the commercial interests to procure the money to continue the work. These men are more like business men than teachers, and they do not come in touch with the youth of the land as the teacher does, so they have little influence upon a student's choice of a course of study.

The demand for meteorological experts has been too small to cause a large demand for instruction in meteorology, differing in this respect from some of the other practical sciences, in which instruction has grown so rapidly in recent years. The business man accepts what good he can get from weather forecasts. It is enough for him to appreciate the work of the meteorologist without realizing that increased attention to the subject in institutions of learning means both more competent specialists and a more intelligent use of the specialist's work.

Of the more than 400 institutions authorized to give collegiate degrees in the United States less than one-third offer a course of instruction in meteorology; and as far as I have been able to learn, in only one of these does a teacher give all his time to the subject. In most of them only a small part of a teacher's time is available. In fact, with a few exceptions, whether meteorology is taught or not depends upon whether some one in the faculty (or an obliging official of the Weather Bureau) can add the work of giving this course to the duties for which he is specifically employed. Of course, under such circumstances the department never becomes large nor the course of study extended beyond the elemental stage. Often even this course is given in the form of lectures, to which is added a little practical work on the part of the student, sometimes without any attempt at practical work. Under such conditions no department of instruction can become large or really efficient, or contain enthusiastic students.

To increase the general knowledge of meteorology is to increase the efficiency of the Weather Bureau. Can this increased knowledge of meteorology be accomplished best by an undergraduate or a postgraduate college course? There is only one answer—by both courses. An undergraduate course is essential; the postgraduate course will come in time, if the first is successful.

The undergraduate course should be sufficiently extensive to give students a good working knowledge of meteorology, but not so extensive as to require too much of their time to complete it. Under present conditions, most students feel that the number of subjects they must take is so great that if meteorology requires more time on the schedule than it appears to be worth they will get along without it. But the work must be sufficient, and must cover the subject so completely that the student will feel that his time has been well spent. The planning of the courses in meteorology is, I fear, often responsible for the small classes. Young people are critical, and they desire to spend their time where it can be done to the best advantage. A shorter course with a large class is better than a long, complete course and a small class. The few who wish a more extended course can take it the next term. The number of students taking this advanced course would be greater than the number starting in a course scheduled as equally long from the beginning. The short course would undoubtedly attract some that later would decide to make the study of meteorology a life work, which they probably never would have done without the shortcourse.

The advanced work will be of great value. It is now largely the custom of teachers to give each advanced student a problem to work upon—a problem requiring a large amount of observation and experimental work. This practice trains the mind and adds to the total sum of knowledge on that subject. The work of advanced students is important in developing any science. Meteorology has had but little help from them.

The greatest work that would be accomplished by the short course would be in fitting teachers for the public schools. The teachers plan what shall be taught in the high schools as well as colleges.

The teachers in both have an immense influence on the pupil in selecting his course. It is a difficult task to force a teacher to introduce a course in a subject which he has never studied and which he probably considers of minor importance. When the teachers in the schools become generally familiar with meteorology they will determine its place in the school curriculum. But will a judicious course in meteorology in the large universities fit the teachers of the public schools? Permit me to give a few local statistics: Ninety per cent of the superintendents and the teachers in the accredited high schools in Nebraska are from the University of Nebraska. All but one of the teachers in the State normal school are from the University of Nebraska. True, few graduates of the University teach in the country district schools, but the graduates of the high schools and pupils from the State normal school do. Surely the boast made by some members of the faculty of the University of Nebraska that "we, the faculty, teach the teachers, and through them the people of the State," has a large basis in fact. Probably all other universities can marshal similar facts. A strong department of meteorology in each would be an important step in increasing the effectiveness of the work of the Weather Bureau.

DISCUSSION.

Dr. **Fassig** (Baltimore). I wish to make one statement with reference to the work of the Johns Hopkins University for the teachers of Baltimore. Two years ago the university planned courses of lectures in geology, meteorology, physics, and botany. The course in meteorology was assigned to me. I had a class of 175 school teachers from Baltimore, and found them a most enthusiastic set of students. Nearly all of those who applied for a certificate from the university for attendance, passed a written examination successfully. I mention this simply as one of the efforts to reach the pupils through the teachers, and to introduce meteorology into the schools by that method.

Prof. **Cleveland Abbe**. The object of teaching meteorology in the schools, so far as the Weather Bureau is concerned, is multiform, but one thing we must not forget is that we want to eradicate ignorance among the people. The school children go home and talk things over, and little by little we are eradicating ignorance—getting the people beyond the ground-hog and sun-spot stage. These things have still a great hold on the people; but we have been fighting a good fight for thirty years and are making progress. Still, we shall have to fight a while longer before they are buried out of sight.

POPULAR LECTURES ON METEOROLOGY, INCLUDING LECTURES TO FARMERS' INSTITUTES, SOCIAL GATHERINGS, SOCIETIES, ETC. ARE SUCH LECTURES VALUABLE IN PROPORTION TO TIME GIVEN? WHAT SHOULD BE THE GENERAL CHARACTER OF SUCH LECTURES?

By Mr. J. Warren Smith, *Columbus, Ohio.*

During the past ten years I have delivered lectures before many different organizations, and I do not hesitate to say most emphatically that I believe this line of work to be profitable to the public and the Bureau.

There is certainly a great deal of misinformation relative to the work of the Bureau. This is demonstrated by the failure of the general public to recognize that our forecasts are but probabilities: to know the time when they are made and the period that they cover; also to recognize the basic difference in methods between the Weather Bureau's making of forecasts and that of the wanderings of irresponsible long-distance prognosticators. In order that the public in general shall understand our work and thus receive the greatest benefit from it, it is necessary that they be more fully informed, and to my mind there is no better way to bring this about than by popular lectures. We certainly fail in our duty if an interested visitor leaves our office without a better opinion of the Bureau and a clearer understanding of our forecasts and warnings. The half hour given to one man in our office could just as well be given to an audience of several hundred.

Not long ago I overheard a conversation between a lady and a well-known business man of Columbus about the probable character of the day. It was then about 8 o'clock in the morning. The lady called attention to the fact that the "newspapers" promised fair weather for the day. The gentleman replied that the newspapers only guessed at it, and that he thought "we could guess just as well as the newspapers, the only difference being that the newspapers had their guess published." This gentleman apparently had not the slightest knowledge of the fact that the "newspaper guess" was made from carefully considered observations fully twenty-four hours before his guess was thought of. Men whose work calls them out of doors a great deal can make very accurate predictions of the weather a few hours in advance, but ninety-nine out of every hundred when asked to try making predictions in the morning for the next day will say that they are utterly unable to do it except when the atmospheric conditions are well defined.

The wider use of the weather maps in our public schools and the increased space given to meteorology in the text-books on physical geography are causing our work to be better understood by the younger generations; yet we can supplement this text-book and map propaganda by popular explanations and demonstrations in the shape of lectures. Opportunity should always be given for questions and discussion at the close of a lecture, for in this way we learn the facts that interest the public and the weak points of our own work.

The general character of the lecture must depend upon the audience. One must not give the same lecture before a school, a literary society, or a social club that he would deliver before a scientific organization. Often we reach beyond our audience. We are so familiar with the terms we use that we forget they may be greek to the average listener. The lectures must be thoroughly practical, direct to the point, and couched in plain terms. They can not be too plain. I well remember a lecture before the masters of the Boston high schools which I thought was plain and practical in the extreme, yet up to the dignity of the occasion,' when a question was asked which illustrates my point. A gray-haired master of a high school asked, in all seriousness, "Whether a cold wave would be as severe if it should move westerly and rebound against the Rocky Mountains and then come east as it would be if it moved directly east in the first place."

Sometimes it will be found necessary to vary the lecture somewhat after reaching the hall, and even after beginning to talk.

I went into a little town in Ohio, two years ago, to address a farmers' institute. There was a long stage ride, and we did not reach the hall until the speaker that preceded me had begun his address. I had expected to speak to the usual gathering of farmers and their wives, but found instead not a dozen farmers in the hall. It was in a small manufacturing town on Saturday evening, and the audience consisted almost entirely of young people. A lecture for the benefit of the farmers would have been voted a pretty dry affair by them, and I was consequently obliged to give them an address entirely different from that which I had planned.

The work at farmers' institutes is, to my mind, among the most practical that can be done. In Ohio the name of the Weather Bureau section director is among those of the extra speakers in the State board of agriculture's institute work.

A speaker is invited to the farmers' institutes because the farmers wish to know something about his subject. It is no uncommon thing after talking for three-quarters of an hour to spend half an hour more in answering questions. Here again one must use discretion in selecting his subject. He should familiarize himself with the principal crops of the community and direct his address accordingly. I have a large number of lantern slides, and always use them wherever possible to illustrate my discourse.

In order to carry on the work of his office properly the Weather Bureau official must be familiar with the agriculture of his State. At these farmers' institutes the Weather Bureau official can explain the work of the Bureau, and arrange for a more complete distribution of the forecasts and warnings, at the same time he is meeting the leading agriculturists of the State, learning the crop interests of each community, enlarging the scope of his work, and most certainly increasing its effectiveness.

I urge more farmers' institute work upon the gentlemen present as time well spent and well used.

DISCUSSION.

Mr. E. W. McGANN (New Brunswick, N. J.). I had a great deal of experience in talking to the farmers of New Jersey last winter. I was listed to give twenty-three addresses at various institutes held in the State, and never was so much surprised in my life as at the general ignorance of the people as to the work of the United States Weather Bureau. I told them very frankly that they were contributing their share of over a million dollars a year for the support of this service, and it was but right that they should know something of the work done by the Bureau. My subject at all these institutes was forecasting—how forecasts are made and how disseminated—covering the whole ground. The central office kindly furnished me with a full set of instruments, and I had a case made so that I could conveniently carry them all in one box. I started out with some want of confidence, and wrote my lecture out in full, taking about an hour and a quarter to read it, but I found on meeting the other lecturers that they did not read, and I realized that even if you had time to read a dry, scientific lecture to the farmers, they would fail to appreciate it, and you would fail to interest them. So, in my lecture, I talked, using the instruments, and had two large weather maps with a storm depicted on them, large enough to be seen all over the hall. I explained the modus operandi of making a weather map, how observations are taken, how they are transmitted to Washington, and how the forecaster, sitting in his office, was able to foretell the weather for any part of the United States twenty-four hours ahead. You know farmers are great believers in the moon. You will find many of them who will wait until the moon is full before they will plant lima beans or melons or anything that is going to fruit above ground, while they take the dark of the moon to plant potatoes, so that the tubers will grow. I have known men to lose their chance of a whole crop by waiting for certain conditions, and when the conditions came the weather would be such that they could not plant and the crop would go by. The farmers were very much interested, and the number of requests I have received, asking if I would not come again next winter, shows that they are becoming interested in the work of the Weather Bureau. I think this is one of the most valuable parts of our work. It is the duty of the Bureau to show the people just what it is doing and tell them of the millions of dollars it is saving to the people of this country by its forecasts.

In conclusion I desire to read the following letter, which is self-explanatory:

STATE BOARD OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Trenton, N. J., July 9, 1901.

DEAR SIR: As a part of my work in connection with the State board of agriculture is to encourage our farmers, through our farmers' institutes, to a more intelligent study of the business of agriculture, you may be interested to have my opinion as to the acceptableness and value of your recent lectures on the work of the State and national weather bureaus.

Judging from the manifest interest during your lectures and the questions asked, I believe the farmers are studying the questions presented in such a way as will lead to a wider use of the weather forecasts and a better knowledge of the system.

If this result follows, it is evident a practical benefit will accrue, not only by heeding the warnings, but by using such preventive measures against early frosts as are suggested from time to time. And, further, by a study of the whole subject as opened up, chiefly by your lectures, supplemented by the crop bulletins during the growing season, they themselves may be able to introduce experiments and particular methods of cultivation which will increase and save valuable crops. The subject is a most important one, and I congratulate you on your sensible and popular presentation of the same.

Respectfully, yours,

FRANKLIN DYE, *Secretary.*

Prof. E. W. MCGANN, *New Brunswick, N. J.*

Mr. J. S. HAZEN (Springfield, Mo.). In discussing this subject I must necessarily confine myself to a somewhat limited experience, but from such experience I unhesitatingly speak for the affirmative side of this question.

For social gatherings, my experience is that general information concerning the history, work, and aims of the Weather Bureau, with a description of map making, methods of drawing the lines, a definition of the various terms and symbols used, with a general outline of storm movements and the relation of the daily forecasts to such movements, constitutes about what is desired. Where one can use a lantern the value of the talk is much enhanced. A more primitive method—a large blackboard map—may be used successfully to illustrate much of one's lecture. For small audiences, the Weather Bureau charts, furnished all weather offices, make a desirable exhibit, but they will not do for large audiences. Where the audience is composed largely of teachers, I find a desire for more explicit information concerning the map-making process, how best to use the maps in schools, the methods of receiving and distributing meteorological data, and the principles of making forecasts. The various terms and symbols used on the map should be explained. Show them how reports are received and translated and how the map is printed. Give them an explanation of normal storm movements. When you enlarge their understanding of the weather map you create an interest in the work and aims of the Weather Bureau that will bear good fruit.

Show to the farmer that his ability to produce an increased yield and raise a more extensive range of crops depends upon a knowledge of the climate of his locality. Be explicit. Explain to him what the introduction of alfalfa, the soy bean, kafir corn, and new and improved varieties of wheat has done for the farmer of western Kansas and other semiarid regions of the West. Make the matter personal. Illustrate by showing the pecuniary advantage of the knowledge. In a matter of dollars and cents the farmer is as keenly alive to his interests as are we to ours. Make him understand the absolute relation between climate and crops, and prove to him that the restriction of certain crops by certain climatic elements, especially temperature and rainfall, is absolute. "Nature is an exacting mistress." She bounds her corn fields on the north and south by isotherms, and the restriction of her boundaries on the west is as sharply defined by the rainfall line of 22 inches. Of course, the farmer may for a season of abnormal rainfall raise bountiful crops of corn beyond this well-defined limit, but the view of deserted villages and abandoned homes to the west of this line should be a sufficient warning that he can not persistently overstep nature's boundaries and hope to escape the penalty. When the farmer understands how absolutely rainfall and temperature limits successful corn growing, we will no longer see the disheartening spectacle of burned-out corn fields and ruined Western farmers striving to get back to the East. When we have taught the farmer the utter impracticability of attempting to raise corn in a region which receives less than 22 inches of rainfall annually, we shall have given him something of value, and which he will appreciate.

The value of such talks would seem to be limited only by the interesting and practical information you can convey to your audience; but you should not ignore the far-reaching dissemination that may be secured by aid of the press. The newspapers, as a rule, want interesting matter, and it should be your business to see that they get all that the Bureau has to give out. Give them as much of your talk as they want, and if the reporters do not have time to secure a synopsis of your article, take it to them. They will appreciate your courtesy. If your talk has been interesting and instructive to your audience, it will be worth publishing, and will be read by the larger audience reached by the newspapers. We thus utilize the press, by being permitted to use its unrivaled facilities, for disseminating and broadening popular knowledge concerning the work and scope of the Weather Bureau.

Professor MARVIN (Washington, D. C.). I would like to mention, in reference to Mr. McGann's remark about the equipment of instruments he had, that the object of the central office is to supply those who are delivering lectures requiring apparatus with instruments as far as possible. Unfortunately, the instrument division is always in an exhausted state, and we generally allot instruments we expect to purchase long before they are received from the manufacturers. We have no stock on hand, but we have some instruments not in condition for regular observations—not thoroughly serviceable—that can be used for illustrative purposes, and the office will furnish these as far as possible.

Mr. CHAFFEE. In answer to the question whether the time devoted to these lectures before farmers' institutes gives a result commensurate with the time devoted to them, I would say emphatically, Yes. I have had the pleasure of lecturing before schools, farmers' institutes, social and other like gatherings, and in no instance, whether the time devoted to the lecture was long or short, did I feel that it was wasted. The farmer is engaged in a pursuit which we desire to benefit and which the Bureau was organized to benefit, and I have found farmers to constitute the most grateful audience that any official of the Bureau can talk to. Their attention should be called not only to the methods of collecting reports and to the reliability of the data upon which forecasts are made, but to the fact that there are times when it is of the most vital importance to farmers to know what the weather of the coming twenty-four hours is expected to be. Every farmer has had just such occasions. Now, where can he get this information? We have the best means of collecting and disseminating it. We are the most reliable source from which he can get this information, and he should be made to understand this. In every case where I have lectured before any body of farmers I have found the results most satisfactory.

Mr. MITCHELL. All that has been said regarding forecasts and warnings can be emphasized when applied to Florida. We are peculiarly situated there, and, notwithstanding the fact that we are somewhat remote from headquarters and at times detached by telegraphic interruptions, we have never had a failure or a complaint during the past seven years. I am not complimenting myself, but the Bureau. The last legislature appropriated $5,000 for farmers' institute meetings. I had the honor of being elected instructor in the State college last winter, and I expect to be able to use some of that fund during the coming season. Now, when it comes to the distribution of forecasts and warnings, it is doubtless a matter of some importance to those who live in the East, perhaps of less importance to those who live in the subpolar regions, and possibly of importance to the hot interior of Kansas, but to us in Florida it is absolutely vital, and were the issue presented to farmers, "Shall the Weather Bureau or the post-office be abolished?" they would say, "Let the post-office go; we can't live without the Weather Bureau."

Professor MOORE. Mr. Mitchell has the distinction of being the man who was specially commended for a violation of orders. Jacksonville is the headquarters from which forecasts of frosts for the important interests of Florida are distributed. On one occasion there was an interruption of telegraphic communication which he did not know of. At any rate he received no warning from Washington to distribute a frost warning and no authority to make a forecast, but he saw there was an emergency confronting him. The reputation of the Bureau was at stake and his people needed a frost warning, for frost threatened to come, so he violated orders and issued a warning to the State of Florida that was perfectly verified. The Bureau got credit, and he himself was commended.

Mr. CLINE (New Orleans, La.). I want to say one word regarding lectures to farmers' institutes. I do not believe the Weather Bureau official gives more valuable time to anything than to these lectures, and I believe the Department should ask for an appropriation to pay transportation and expenses for this purpose. If we expect farmers to heed our warnings, we must instruct them how to use them. This is the way to instruct them. I find the farmers always interested, just as Mr. Smith has found them. We can instruct them by going among them and lecturing to them.

Professor **Abbe**. I approve Dr. Cline's suggestion. Perhaps a paragraph might be added to the appropriation bill making it the duty of the Weather Bureau to educate a corps of lecturers to address farmers' institutes.

Dr. **Fassig**. I think the object might be accomplished under existing regulations by so timing the visits to farmers' institutes as to correspond with the inspection visits to voluntary stations.

Professor **Moore**. In setting aside a certain sum to pay for inspections once in two years the object was to enable the section director to go out and meet the voluntary observers cooperating with the section center, and have his expenses or a portion of them paid. It seems that it is only necessary for him to time his inspections to agree with the dates of the farmers' institutes to accomplish both objects at the same time. We must approach these matters carefully and gradually. Congress has been very fair with us. We have tried in all our estimates to be conservative, and to be sure that for every dollar we spend we can give a good account. I agree with you that it would be a good thing if every section director could have a sufficient allowance to travel and lecture before all farmers' institutes at least once in two years, and we hope that time will come. It will come if we give a good enough account of the money we spend. Congress has given us an increase every year. However, when we come to apportion that increase so as to secure the best returns we always find we do not have as much as we want, so we have not as much for this purpose (the inspection of voluntary stations) as we would like to have. It is better to move slowly and keep our expenditures within economical boundaries than to travel too fast and possibly authorize expenditures that subsequent development may not justify. This conservatism has probably deterred us from asking more liberal appropriations. Probably in the future we shall ask for a little more.

Mr. **Richards**. It seems to me a good idea to notify your voluntary observers of your visit and ask them to invite their friends to meet you to discuss or learn something of the practical workings of the Bureau. In this way you would bring before many people the working of the Bureau without additional expense.

Mr. **Loveland**. In Nebraska all lecturers at farmers' institutes have their expenses paid. I think this is perhaps the case in some other States. The organization of farmers' institutes is progressing rapidly, and the appropriation is increasing very fast. If the Weather Bureau officials be included in the regular list of speakers I think the State would pay their expenses.

Mr. **Berry**. We have at last secured a very small fund for the inspection of voluntary stations, and I hope none of it will be diverted from the purpose for which it is intended. Visit the institutes whenever it is practicable to do so, but not with the expectation of defraying your expenses from this fund, unless the institute is on the way to the voluntary station to be inspected and provision is made for the entertainment of the lecturer. I hope the small sum allotted for the inspection of voluntary stations will be used exclusively for the specific object for which it has been provided.

CLIMATE AND VEGETATION.

By Mr. Charles E. Linney, *Chicago, Ill.*

The farmers of the United States do a large amount of experimenting each year with new varieties of fruits, vegetables, and cereals. These tests are undertaken with little or no regard to the previous climatic conditions under which the plant grew, whether it came from the adjoining State or the opposite ends of the earth. Many failures necessarily result, with much loss of time and money. Climatic conditions are unfavorable in most instances, for methods of culture are learned with comparative ease, although many failures no doubt result from unfavorable soils. You can not grow the orange, lemon, banana, or fig outside of our warm Southern States; you can not grow firs, spruces, hemlocks or balsams with profit on our western prairies, nor corn in the more northerly latitudes. And yet climatic conditions are learned with comparative ease and to a certain extent can be governed. Plants by slow culture and gradual extension can be acclimated to regions many miles beyond their usual lines of latitude.

The climatic conditions of the United States are now established with a fair degree of accuracy, and the information is available to all seekers. However, it is only recently that an attempt has been made to give the plant zones. This work was undertaken by the Biological Survey of the Department of Agriculture, and the results were published in 1898 in a pamphlet called "Life Zones and Crop Zones."

Physical geographies have heretofore paid some attention to the question of plant and life zones, but it has been usually very superficial, consisting of an elementary discussion of the climatic conditions associated with certain well known and easily distinguished plants. Thus Houghton says:

> Plants require for their growth certain conditions of light, heat, and moisture, and since the requisite amount of each of these varies with different species of plants, we find in every climatic zone a characteristic flora. * * * Moisture and heat are the prime essentials of vegetation, and it is on their distribution that the distribution of vegetation is principally dependent. The influence of heat and moisture is noticed as we pass from the equator to the poles, or from the base of a tropical mountain to its summit, thus arises a horizontal and a vertical distribution of vegetation.

The horizontal zones of vegetation have heretofore been designated the tropical, subtropical, warm temperate, cold temperate, subarctic, and arctic, each with its distinguishing climate and vegetation, although overlapping each other somewhat. The Biological Survey, however, has given a different division, calling the three life zones of North America the tropical, austral, and boreal, subdividing these into the tropical, lower austral, upper austral, transition, Canadian, Hudsonian, and arctic—seven in all. The tropical is indicated by the region in the extreme southland, including the southern parts of Florida, Central America, the lowlands of Mexico, and the lower Gulf region; the austral covers the whole of the United States and Mexico, except along the extreme north and south, while the boreal covers the entire northern part of the continent to the polar regions, and also a few peaks of the higher mountain systems within the United States.

Subdivided and considered for temperature, the survey finds that the tropical zone is confined within that area which has a total quantity of heat approximating at least 26,000° F. (14,400° C.). This is obtained by considering 43° as the beginning of plant activity. With 43° as a beginning, the effective temperature or degrees of heat (daily mean normal shade temperatures) in excess of this number were added together for the several stations considered in the different zones, beginning when the normal mean in spring exceeded 43° and continuing until it fell to or below that point in the fall. With this as a basis the tropical was found to lie within lines which were bounded by an annual quantity of at least 26,000°. The lower austral was confined to a region which required a total quantity of at least 18,000° F. (10,000° C.); the upper austral to a region and to plant species which required at least 11,500° F. (6,400° C.); the plants of this zone apparently can not endure daily a summer temperature during six consecutive weeks of 79.8° (26° C.); the transition was confined to a region which required at least 10,000° (5,500° C.), the plants of which were apparently unable to withstand six consecutive weeks of daily summer temperature averaging 71.6° (22° C.); and the Canadian, Hudsonian, and arctic extending thence northward into the polar region, their southern limits being marked by the isotherms for the six consecutive hottest weeks of 64.4°, 57.2°, and 50°, respectively. The conclusion of the survey in regard to the distribution of plants and animals is as follows:

> The northward distribution of terrestial animals and plants is governed by the sum of the positive temperatures for the entire season of growth and reproduction, and the southward distribution is governed by the mean temperature of a brief period during the hottest part of the year.

Vegetation throughout the greater part of the United States lies within the temperate (or austral) zone, and is dormant during several months of the year. It is within this region, however, that our largest staple food crops are produced. Germination and growth are wholly dependent upon the temperature in excess or deficiency of 43°. Adamson says that—

> the development of buds is determined by the sum of the daily temperatures counted from the beginning of the year.

But it is likely that a more accurate expression would be the sum of the daily temperatures from the cessation of winter. Linsser says—

> that the sum of the temperatures above zero centigrade (32° F.), which is necessary for a certain development of similar plants in two places, is in direct proportion to the sum total of the temperatures above zero (centigrade) at the two stations.

The adaptability of plants to climate is so great that it is questionable if the heat units obtained for one latitude would be those required in a more northerly or southerly latitude. Take wheat, for instance; it can be grown successfully within the semitropical zone and thence northward beyond the cold temperate zone, a range of probably 20 to 25 degrees of latitude, and in the northern limit the rate of growth is the more rapid. Hoffman, in a series of experiments at Giessen, Germany, and Upsala, Sweden, found that the time of the blooming of the syringa vulgaris (common lilac) was April 29 at Giessen and June 17 at Upsala. The heat units received were 1,482° and 1,433° C., respectively, practically the same. In the first ripening of fruits, 11 species being considered, the ratio between the two places was as 100 to 82, while for the interval between the first bloom and the ripening of fruits the ratio was as 100 to 93. It is commonly observed, often to the great loss of the farmer, that seeds from plants brought into a northern country from the south produce plants which will not mature, for they are caught by the early frosts, while, vice versa, the northern plants in the south ripen far earlier than the native species. Thus it behooves the seeker after seed to stay as nearly as possible within his line of climatic latitude, or draw from a region slightly to the northward.

It has been found that the average daily temperature in the shade must be above 39.2° F. (4° C.) for sugar cane, and 46.4° F. (8° C.) for potatoes, if one desires to observe the effects of germination and growth. And the higher the temperature the quicker the germination and growth. Huberlandt found that with a temperature of 49.0° (9.4° C.) it took beet seed twenty-two days to germinate, while with a temperature of 60.4° (15.8° C.) only three and three-fourths days were necessary. With these plants, also, the maximum yields were secured by planting the 1st of May rather than the 1st of March or April.

The temperature records of our principal cereal States show from 2,700° to 3,390° of accumulated heat (above freezing) to be the normal in the period of growth of wheat, rye, oats, and barley; March to June (one hundred and twenty-two days) being the usual time in the Ohio Valley, middle Mississippi and lower Missouri valleys, and April to July in the upper Mississippi and Red River of the North valleys. For corn and other grains, grasses, and fruits, that have a season extending from about March to September (two hundred and fourteen days), 4,665 to 7,000 heat units (above freezing) are the normals throughout the same region.

Rainfall is, next to temperature, the most important climatic element. The amount required for the growth of vegetation has been ascertained many times and for a large variety of plants, but with rainfall, as with temperature, there seems to be a wide range, possibly because plants adapt themselves to their environment. In addition to the amount of rainfall required, it is essential also to know the frequency of fall, the rapidity of fall, and the average amount of each fall. Thus a rainfall of 4 to 5 inches per month would, if it came in showers of a half to three-quarters of an inch, provide ample moisture for the most thirsty farm crop, but if the same amount were dashed down in one or two heavy showers, the results would not be favorable. Other points of value are the probability of rainfall, the length of time rain may reasonably be expected to continue after it has set in, the extent of the country covered, the temperature, humidity, sunshine, and wind before and following the rain, the condition of the ground water, drainage, and composition of the soil, and the moisture characteristics of the plant.

Experiments carried on by Professor King, in Wisconsin, indicate maximum yields of corn with 25 to 30 inches of rainfall during the crop season; oats 15 to 20 inches, and barley 12 to 2C inches. It appears also from experiments in Germany that about 5 inches of water to the ton of dry matter should be sufficient to produce a wheat crop of 15 bushels per acre; 6 inches to the ton to produce 20 bushels to the acre; nearly 8 inches for 25 bushels; 9 inches for 30 bushels, and 12 inches for 40 bushels per acre. Professor King, however, in considering the rainfall of the San Joaquin Valley, the evaporation which would likely occur, and the soil water, thinks that 7.5 inches of water per ton not too much to secure 15 bushels per acre; 9 inches for 20 bushels; 10.5 inches for 25 bushels; 12 inches for 30 bushels, and 15 inches for 40 bushels. From which it would appear that our semiarid West can, during most seasons at least, raise a fair crop of wheat, other conditions being reasonably favorable. Mr. Mark Carleton has recently given like testimony in an article in the Year-Book of 1900, in which he shows that good average yields of wheat are steadily secured by the farmers of Russia in parts having much less annual and seasonal rainfall than our so-called semiarid region.

The normal rainfall during the season of growth of small grain in the Ohio, middle Mississippi, and Lower Missouri valleys is from 11.3 inches to 14.7 inches, and decreases from 10.6 inches to 8.3 inches over the upper Mississippi and middle Missouri valleys to the Dakotas and Red River of the North, the average wheat yield being from 10 to 24 bushels; oats from 18 to 40 bushels, and barley from 15 to 30 bushels. The normal rainfall from the 1st of March to the last of September decreases from 26.3 inches in the middle Mississippi and Ohio valleys to 24 inches in Illinois and Iowa; 21 to 23 in Michigan, Wisconsin, and Nebraska, and 15 inches in North Dakota. This gives an effective rainfall for the corn season of about 16 to 18 inches in the Lower Missouri, middle Mississippi, and Ohio valleys; 12 to 15 inches in the lake region, Upper Mississippi, and middle Missouri valleys, and from 10 to 12 inches in the Dakotas and Red River Valley. Professor King finds, in summarizing the results which should be obtained from the effective rainfall in our principal cereal States, if the same were practically used in plant growth and grain development, that an average yield of 40.3 bushels of barley, 65 bushels of oats, and 71.5 bushels of corn per acre should be had. These yields are in fact attained by our best farmers in our most favored seasons and on the best soils.

In the year 1895 19.6 inches of rain in Illinois produced an average yield of 37.4 bushels of corn, 16.8 inches of rainfall in Indiana produced 32.8 bushels of corn, 21.4 inches of rainfall in Iowa produced 35.1 bushels of corn, 24.6 inches of rainfall in Missouri produced 36 bushels, and 18.9 inches of rainfall in Kansas produced 24.3 bushels of corn. In the same year 10.1 inches of rainfall in Illinois produced an average of 11 bushels of wheat per acre, 20 bushels of barley, and 24.4 bushels of oats; about 6 inches of rainfall in Indiana produced 9.2 bushels of wheat, 15 bushels of barley, and 22.9 bushels of oats per acre; 13.2 inches of rainfall in Missouri produced 12 bushels of wheat, 15.3 bushels of barley, and 27.7 bushels of oats per acre, and 9.4 inches of rainfall in Kansas produced 7.7 bushels of wheat, 14.4 bushels of barley, and 17.9 bushels of oats per acre. On deep, fertile soils, therefore, good paying yields of small grain may be expected with rainfall as low as 7 to 8 inches, and large yields when the rainfall approaches 12 to 15 inches during the growing season.

Sunshine as a factor in plant growth is probably third in importance, and closely allied to temperature. It is usually determined by the inverse method, observations of clouds and cloudiness, rather than the actual sunshine, although of late years many of our stations are equipped with sunshine recorders, and the approximate hours of sunshine are obtained with a fair degree of accuracy.

The effect of sunshine in determining the form of plants is well known. If a plant germinate beneath a box, board, or stone it does not spread out at random, but takes the shortest path to the sunlight, where it spreads out in its usual form. The form and direction of growth of every branch, leaf, or shoot of a plant is controlled largely by its accessibility to the light. This is true even to the development of the branches, for these bud and grow where the leaves can unfold to the light with the least obstruction, and a symmetrical plant is usually an unobstructed one. The agriculturist should meet this need of light in the planting and cultivation of his fields.

Just how much sunshine is essential has not been fully determined, so far as I can learn, but that plants differ much in their requirement, and also adapt themselves rapidly in this, as in temperature and moisture, is well known. An almost cloudless sky for months will not harm many plants if they have an abundance of moisture, and it is probable that others would be equally immune if they were gradually acclimated. Experiments in Paris, carried on through a period of five years, in which sunshine, heat, rainfall, and evaporation were carefully measured from March to July, inclusive, showed that a considerable increase in crop yield was obtained when the percentage of sunshine was greatest, although at no time during the period was there a very marked difference in the amount of sunshine measured.

Other climatic elements which can be considered of value in relation to vegetation are wind direction, wind velocity, and evaporation. The wind direction and velocity of all parts of the United States have been determined with reasonable accuracy, and should be available to anyone seeking this information. The damaging effects of high winds can be largely controlled by the cultivation of wind-breaks. These will quickly and permanently prevent drifting of the soil, too rapid evaporation by high winds, broken and fallen grain, due to the same cause, and, to a considerable extent, winter killing. Professor King finds a marked decrease in the rate of evaporation for a considerable distance to the leeward of a row of trees or a hedge. He also recommends for a windy country, where light and comparatively porous soils predominate, small, narrow fields, with intervening fields of clover, alfalfa, or grass, for even these small plants serve as a marked barrier in drifting soils.

The evaporation from soil and water surfaces has not been ascertained with accuracy for a large part of our country. On land surfaces it is found that while evaporation is heavy directly after a rain storm, it diminishes rapidly as the upper layer of earth becomes dry, and practically ceases after a short period of time. In the more modern and skillful farming this is aided by tillage, and if a dust mulch can be maintained evaporation is reduced to a minimum. This seems to be especially the case in our Western States, where a loose soil in itself becomes a mulch. Professor King found that the rate of evaporation in the San Joaquin Valley fell to the small amount of 0.8 of an inch in one hundred days of almost continuous sunshine, and did not exceed 1.5 inches in a second trial at a different season.

If the opposite effect is desired, i. e., more rapid evaporation, firming the soil with a roller to establish capillarity will quickly produce the desired result, except on lands which need underdrainage, when it alone will suffice. Agricultural prosperity is the basis of all prosperity, and its success depends upon the adaptation of the plant to the climate. While it is scarcely the province of the Weather Bureau to determine what plants are adapted to this or that climate, I think I am justified in saying that we will at all times gladly cooperate with the biologist, to the end that this information shall become available to our agriculturists.

DISCUSSION.

Mr. J. WARREN SMITH. I am sure that the general public does not understand the close connection between the weather and the growth and ripening of vegetation, and I doubt very much if the majority of us in the Bureau appreciate the matter as we should.

Instead of taking the sum total of the temperatures above 40° I believe that we should consider only daytime temperatures; possibly the total insolation must alone be taken as the basis of calculation. Is it not true that the increasing insolation in more northern latitudes causes more rapid growth and earlier maturity than in more southern districts, while the more rapid growth and increased sunshine produces fruit and grains of a firmer, harder nature?

I would give sunshine a more prominent place than has been given it, particularly in the maturing of crops. Two years ago the sugar beets grown in northern Ohio gave a very high per cent of sugar. Last year there was much complaint on the part of the growers, because the experiment-station test made the sugar content much lower than the previous year. They did not understand why there should be such a difference; neither did the station officials until a visit to our office and an examination of the voluntary observer records in the sugar-beet district was made. These showed much more cloudiness at just the ripening period all through the beet-growing district last year than the year before. A simple thing, yet all important in its results.

It may not be within the province of the Weather Bureau officials to determine the proper climatic location for the various crops, yet I do believe that it is a distinct part of our duties to work out the relation between weather and crop growth. We must not draw conclusions too quickly, but I am sure of one thing: we shall find that the period when crops are greatly injured by bad weather or benefited by good weather to be a comparatively short part of the whole period of their growth, particularly when the yield departs very much from the normal.

I believe it is our duty to the public to make such studies. Then, when the Bureau can make predictions for a season in advance, as I believe it will ultimately do, we shall take our true place in the affairs of the community.

CLIMATE AND MAN: WITH SPECIAL REGARD TO CLIMATE AND CLIMATIC ELEMENTS AS CURATIVE OR CAUSATIVE AGENCIES OF DISEASE.

By Dr. W. M. Wilson, *Milwaukee, Wis.*

The distribution of the climatic elements of a country determines its fruits and flowers, its industries and activities, and the character and temper of its people.

The world's great workshop is bounded by the tropics and the arctics, and neither the torrid zone, where life is made too restful by nature's bounteous provisions, nor the frozen North, where existence must be wrested from the unwilling sea and soil, are conducive to the highest development of the race. Practically all of the world's great industries are centered within the limits of the temperate zone, and thus far every effort to plant a great nation outside this narrow belt has proved a disastrous failure. Gigantic schemes, with elaborate and refined preparations for the colonization of the tropics, have always been met by the insurmountable barrier of death and disease, until the West Indies have come to be called the "Graveyard of Europe."

France has been one of the foremost nations in the promotion of these enterprises, and French literature is full of ingenious explanations for each successive failure, which, after a more or less devious path through the social and political questions of the time, usually arrive at the same fundamental conclusion, that the climatic conditions of the tropics are unsuited to European civilization.

An English authority, Benjamin Kidd, has pronounced in no uncertain terms against the possibility of the white man ever being able to pass the tropics, assuming that past experience has shown beyond the shadow of a doubt that nature, by the interposition of the deadly climate of the tropics, has placed a natural barrier in the way of further progress in that direction which may not be passed with impunity. With all due regard to these eminent authorities, one who approaches this subject with an unbiased mind can not fail to be impressed by the absence of any attempt to classify or analyze the characteristics of the various maladies which produce such disastrous results and the perfunctory way in which the whole responsibility is placed upon climatic conditions.

The influence of climate upon the origin and cure of disease is a question of very great importance, not only to promoters of industrial enterprises in tropical countries, but to the great army of health seekers that make annual pilgrimages to the famous health resorts in search of a climate which will restore youth or cure disease. It is a matter of common knowledge that most infectious diseases exist only within certain limited areas. Some have their home in the tropics; some, like tuberculosis, acknowledge no geographical limitation, and seem destined to overspread the whole world; while others, like diphtheria and smallpox, are gradually being crushed out by modern prophylactic methods, and may even be tending toward extinction. On the summit of high mountains infectious diseases are unknown, and in the "farthest north" the earth and air and sea are as free from harmful germs as though sterilized in the laboratory of the chemist.

The tendency of diseases to become localized in their distribution has given rise to a general belief that the cause for their origin and propagation must be found in the prevailing climatic conditions, and that for this reason certain climates, especially the tropics, are absolutely unfitted for the habitation of the white man, while others are endowed with healing qualities akin to those ascribed by the ancients to certain springs. During the past twenty-five years, however, scientific experimentation with reference to the origin and propagation of infectious diseases has revealed some startling truths, the discoveries in this field of research undoubtedly constituting the greatest achievements of modern medicine. It is now positively known that many of the diseases heretofore ascribed to climatic conditions result from the presence within the body of a specific germ or living organism, the life history of which is as well known as that of the most common insect, and that by proper hygienic precautions, one may live in the very presence of this most deadly enemy in comparative safety.

The discoveries have a most important bearing upon the subject of medical climatology; for, while climatic conditions may in a measure favor the development and activity of the germs of disease, the responsibility for their invasion of the human body is thus shifted from impersonal, irresponsible climate to a responsible individual, who, when having knowledge of the proper prophylactic measures to be employed, fails in the necessary hygienic precautions, must suffer the consequences of neglect. The thinkers of to-day are gradually reaching the conclusion that the healthfulness of any locality or section is not so much a matter of climate as a matter of hygiene; and when medical science shall have studied the diseases indigenous to the tropics with the same zeal and success that has attended the investigations into the etiology of the ailments of the temperate zone, one can live in a tropical country, under proper hygienic precautions, perhaps with less personal comfort, but certainly with no more danger, than in the most favored spot in our own country.

Smallpox has few terrors for the present generation, but this scourge has claimed its victims by the tens of thousands. It is not climate, but scientific sanitation and hygiene, that has wrought the change. Yellow fever will no more wreck our Southern cities when the breeding pools of the mosquito are eradicated; and when the so-called climatic diseases of the tropics are as well known and the proper precautions observed that "graveyard of Europe," the West Indies, will become the veritable garden of the world, and the words "acclimated" and "immune" will disappear from our language.

Climate as a cure for disease, in the broadest sense, rests upon the same general principle. A specific disease must be reached by a specific remedy, and, strictly speaking, climate, so far as known, possesses no qualities which would entitle it to such a position in the materia medica. The claims made by the promoters of certain health resorts that the richness of the air in ozone, the resinous gases from the pines, the peculiar purity of the atmosphere in a particular locality, or the elevation or aridity of the air acts as a specific in certain diseases, are not generally based upon scientific investigation, and usually have their origin in the fertile brain of the advertisement writer.

It is common knowledge that the principal components of the atmosphere are in practically the same proportion the world over, that the amount of moisture varies with the locality and season, and that rarefaction results from an increase of elevation; and while it is true that elevation tends toward increasing lung capacity and that excessive humidity retards in a measure the excretory action of the skin, it has not been shown that the absence of moisture has any specific influence upon those diseases for which a dry climate is so frequently recommended, or that a rarefied atmosphere is essential to the destruction of the germs of disease. On the other hand, there is ample experience to show that persons suffering from troubles associated especially with tuberculosis are frequently benefited by a residence in the humid air at the level of the sea as well as in the dry and arid atmosphere of our Western plains.

We must, therefore, look further than to mere climatic conditions for the cause of the cures which sometimes certainly do result from a change of residence. The human organism, both in health and disease, is so complex in its operations, so delicately poised, and the relation of the mind and body so interdependent, that environment, whether it be of climatic or of social conditions, while not acting directly, may, through the senses, exert a powerful influence upon the vital forces. This influence of environment is all the more potent in that class of diseases in which continued ill health and lowered vitality allow the shattered nervous system to respond readily to external impressions, and in these cases a change of residence is frequently of the greatest benefit. Nature itself is the best doctor, and, when supported by environment and proper medication, may be relied upon to use all the forces at command against the inroads of disease. That climate may play an important part in the curative process is not denied, but that the climate of certain localities possesses any peculiar properties which act as a specific on certain diseases is neither borne out by scientific investigation nor unbiased experience.

In the selection of a place of residence, climate should be considered only in its effect upon comfort and congenial surroundings and with a view to a constant outdoor life. Pure air, which can be found almost any place outside of great cities, and the maximum amount of sunshine are the two essentials.

That the temperature is not important is shown by the excellent results obtained by a residence in the Adirondacks, where the cold of winter is frequently intense. That a dry atmosphere is not essential is evident from the equally good results obtained in the arid climate of our western resorts and the humid atmosphere of the Southern States. That rarefaction is not a requisite is shown by the cures effected both at sea level and at high altitudes. With complete relief from care and anxiety, good food, pleasant occupation, and a constant outdoor life, one may fight a winning battle against disease in almost any climate, whether it be in the arid, rarefied atmosphere of Colorado or New Mexico, the soft and genial warmth of Florida, or the more rigorous climate of the New England States.

INFLUENCE OF CLIMATE ON ANIMAL LIFE.

By Mr. R. H. DEAN, *La Crosse, Wis.*

It has long been a common belief that climate is the paramount factor in controlling the abundance and distribution of animal life, and that climate to some extent modifies the form and organism of animals. The limits of this paper preclude any treatment of the last proposition, and only the influence of climate on the distribution of animals will at present be discussed.

The old geographers[a] fixed rather rigid boundary lines for life zones, making of the tropics and arctic circles barriers which bird and beast scarcely dared approach. Some very general laws were recognized as fairly well established, the most important among them being one that stated that the number, size, strength, and beauty of animals decrease from the equator to the poles. Observed facts seemed to support this general belief. Elephants, hippopotomi, camels, tigers, monkeys, and many other species of quadrupeds and the birds of brilliant plumage inhabited the tropical climates exclusively and in great numbers, while polar bears, reindeer, arctic foxes, auks, and a few other animals were found in less abundance in the arctic regions only.

About a quarter of a century ago the study of zoology and kindred sciences received a great impetus from the works of a brilliant array of scientists, and biology became a familiar term. The general tendency of these writers was strongly against the popular belief stated above; and nearly all of them minimized climate as a factor in the distribution of animals, while some of them maintained that it was scarcely a factor at all. Wallace[b] says—

> It was long thought, and is still a popular notion, that the manner in which various kinds of animals are dispersed over the globe is almost wholly due to the diversities of climate and vegetation. There is much to favor this belief.

He then proceeds—

> A more detailed and accurate knowledge of the productions of the different parts of the earth soon showed that the explanation was quite insufficient.

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[a] Swinton's Grammar-School Geography, p. 10.

[b] Geographical Distribution of Animals, p. 5.

And the whole tenor of the excellent and fascinating works of Wallace is to ascribe to other causes than climate the distribution of animals. Other writers held similar views. Darwin,[a] among the more cautious, says—

> Climate plays a most important part in determining the average numbers of a species, and periodical seasons of extreme cold or drought seem to be the most effective of all checks. * * * Climate [as a check] acts in the main part by favoring other species.

Thus admitting the efficacy of climate as a check to the increase in number of animals and at the same time giving it a secondary influence.

Heilprin[b] says—

> But while in numerous and, perhaps, the majority of instances the limitation of animal groups to certain geographical regions is dependent more upon the physical character of the immediate environment and the nature of the food supply than upon particular conditions of climate, yet it can not be denied that in many cases climate appears to exercise a paramount influence upon distribution.

Semper[c] concludes an argument on the subject with these remarks—

> The results thus laid down * * * justify us * * * * in denying the value frequently attributed, even quite recently, to curves of temperature as constructed by meteorologists.

He further says—

> Hence it is evident that classification of animals according to the climate in which they live * * * has no real value.

He then adds—

> If we assume that if there is a certain degree of heat * * * which is most favorable to the well-being of one or several species of animals, obviously every rise or fall of temperature above or below this favorable point must be to a certain extent injurious to the creature.

This degree of favorable heat Semper calls the "optimum," and makes it the base from which to work. We shall see later how nearly he was approaching the truth.

The problem was and is a complex one. Wallace[d] quoted above, says—

> Every change becomes a center of an ever-widening chain of effects. The different members of the organic world are so bound together by complex relations that any one change generally involves numerous other changes, often of the most unexpected kind. We know comparatively little of the way in which one plant or one animal is bound up with others, but we know enough to assure us that the most apparently disconnected are often dependent on each other.

And further he intimates that they may, in the same way, be dependent on the permanency of climate, or vastly affected by a slight change in the same.

Dr. J. A. Allen had shown that, so far as birds are concerned, it is the temperature which prevails during the breeding season that controls this distribution. This was a step ahead of Semper, and an important advance.

Dr. C. Hart Merriam, of the Department of Agriculture, investigated the subject for a number of years, and in 1890, as the direct results of the biological survey of San Francisco Mountain, gave the first fruits of his labors to the public.[e] It is difficult to overestimate the value of the results obtained and the conclusions arrived at.

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[a] Origin of Species, 5th ed., p. 75.

[b] Distribution of Animals, p. 35, International Series.

[c] Animal Life, p. 103, International Series.

[d] Distribution of Animals, p. 44.

[e] North American Fauna No. 3, Department of Agriculture.

No advance toward the establishment of definite laws for the distribution of animals and plants of equal importance had ever before been made. Dr. Merriam found that "temperature and humidity are the most important causes governing the distribution, and that temperature is more potent than humidity."

The investigation has been continued by the Biological Survey of the Department of Agriculture, assisted by other Government bureaus, including the Weather Bureau. As one result, Dr. Merriam has promulgated definite temperature laws which govern not only the distribution of animal life but of plant life as well; and it has been shown that the faunal zones and floral zones are identical, and are also climatic zones. They are not, it is true, restricted by curves of mean annual temperature, the results in this agreeing with what was advanced by Semper; and the time of the temperature is that of the season of growth and reproduction, agreeing in this with Allen on the distribution of birds. But there were yet other intricacies, and it was found necessary to take one set of temperatures for the limit of the cooler side of the range, and another and entirely different set for the limit on the warmer side. These laws, as formulated by Dr. Merriam and published first in the National Geographical Magazine, December, 1894, were, leaving out of account obvious physical barriers, such as oceans—

> In northward distribution, terrestrial animals and plants are restricted by the sum of the positive temperatures for the entire period of growth and reproduction. In southward distribution they are restricted by the mean temperature of a brief period during the hottest part of the year.

It yet remained to determine what temperature is effective for life, above which temperatures may be considered positive, and what is the "brief period" of the hottest part of the year.

Since animal life is generally inactive as far as reproduction is concerned and most plant life is absolutely inactive at temperatures below and near freezing point, 43 F. was assumed as the starting point for the activity of life; and the sum of all the mean daily temperatures above that point from the beginning of the season, when the temperature reached 43 F., till the end of the season, when the temperature again fell to 43 F., was taken as a minimum equivalent necessary for the reproduction and growth of the species of animal or the growth and reproduction of the species of plant in reference to which it was used. In other words, the species of plants or animals which require this amount of heat will be found on the warm side of an isotherm drawn through a number of points platted from the sums of effective temperatures.

It may be remarked here that the daily mean of the sum of these effective temperatures is probably equivalent to Semper's "optimum."

Lines platted from the sums of effective temperatures thus obtained were found to coincide almost exactly with the boundaries of life zones established from actual lists of plants and animals; hence 43° has been retained as the most probable point for the beginning of life activity.

A period of six of the hottest consecutive weeks of summer was adopted as a working basis for the "brief period" to determine the limit on the warm side of the zones, and the results thus obtained were so satisfactory that no change has since been made.

Applying these principles and rules, the continent of North America has been divided into three primary transcontinental regions, greatly modifying in principle and outline the regions previously recognized. The regions have been called boreal, austral, and tropical. The regions are subdivided into transcontinental zones: The boreal into arctic, Hudsonian, and Canadian; austral into transition, upper austral, and lower austral; the tropical region is of small extent in the United States and has not been subdivided.

The results of these recent researches and surveys have been of immense practical value to agriculturists and stock raisers, aside from their purely scientific value, and their utility will increase in proportion to the rate that the principles are understood and applied. As it is with the rainfall of the growing season that the farmer is generally concerned, so it is the effective temperature that is important to him, and with proper investigation he may know what is the effective temperature for each crop cultivated and animal raised.

SYNOPSIS OF COURSE OF LECTURES IN MEDICAL CLIMATOLOGY TO THE SENIOR CLASS MEDICAL DEPARTMENT UNIVERSITY OF TEXAS.

By Dr. I. M. CLINE, *New Orleans, formerly of Galveston, Tex.*

Medical climatology was added to the curriculum of the medical department of the University of Texas in 1893. The lectures have been delivered weekly to the senior class.

The course, consisting of 30 lectures, was divided into 4 sections. The sections and lectures are as follows:

Section 1.—Meteorological apparatus and methods. Four lectures.

1. The measurement of atmospheric temperatures. The development of the thermometer and different forms of thermometers. The exposure of thermometers and the methods used in obtaining extremes and averages.

2. The measurement of atmospheric pressure. The construction of barometers and barographs and the methods used in determining averages.

3. Instruments used in measuring the motions of the air and the manner in which their records are utilized.

4. The measurement of aqueous vapor. The measurement of precipitation. The determination of average or normal rainfall.

Section 2.—Meteorology most essential to the study of climatology. Seven lectures.

1. The origin of the atmosphere and its relation to the earth. The composition and offices of the atmosphere. The relation of oxygen to the animal kingdom. The existence of impurities. The extent and arrangement of the atmosphere as regards the earth.

2. The control of atmospheric temperatures: radiation, insolation, reflection, absorption, convection, and conduction. Difference in absorption and radiation between land and water.

3. The distribution of temperature over the earth and the factors which produce irregularities.

4. The general circulation of the atmosphere.

5. The cyclonic and special winds.

6. The causes of precipitation. The distribution of rainfall over the earth.

7. Weather maps; forecasting the weather.

Section 3.—General climatology and mineral springs. Four lectures.

1. General climatological features of different portions of the earth.

2, 3, and 4. The mineral springs of the United States and the climatic features of the sections in which located.

Section 4.—Applied medical climatology. Fifteen lectures.

1. Climate and disease. The physiological effects of weather changes and different climatic conditions on the human organism.
2. Pathological distribution of climate in the United States.
3. Influences of climatic conditions and weather changes on the functions of the skin.
4. Phthisis and forms of phthisis as influenced by climate and weather changes.
5. Treatment of phthisis by change of climate.
6. Pneumonia in its relations to climate and weather changes.
7. Malarial diseases in their relations to climate and weather changes.
8. Typhoid fever and the effects of climate and weather changes.
9. Diseases of the digestive system and the influence of climate and weather changes.
10. Diseases of the genito-urinary system and the influence of climate and weather changes.
11. Diseases of the nervous system and the influence of climate and weather changes.
12. Diseases of the circulatory system and the influence of climate and weather changes.
13. Yellow fever and the influence of climate and weather changes.
14. Diphtheria and the influence of climate and weather changes.
15. Other diseases which climate and weather changes appear to influence more or less.

Only two of the above lectures are now available. During the years 1893 to 1896 I prepared the 30 lectures in manuscript form. I had them about ready for publication in November, 1896, when my residence was burned and 20 of the lectures, with my books and papers of reference, were lost. I took up the work again and had almost completed the course of lectures the second time when the hurricane of September 8, 1900, swept my residence and all of its contents away. I expect, however, to rewrite these lectures at some future time.

Very few of the students before whom these lectures were delivered had studied meteorology. This is why the first half of the course of lectures was devoted to apparatus and methods and meteorology.

CLIMATE AND THOUGHT.

By Mr. E. C. EASTON, *Baltimore, Md.*

[Read by title.]

Emerson says in one of his essays that there is a genius of a nation, which is not to be found in the numerical citizens, but which characterizes the society. In like manner there are characteristics in the sum total of atmospheric influences, or climate, which are not clearly discernible in its individual components, or weather. Furthermore, as changes in weather conditions have been found to affect temporarily the mental activities of individuals,[a] so may we expect to find that climatic conditions have tended to create permanent peculiarities of national character and thought. It is quite evident that nations differ greatly in this respect; and it is more than probable that these differences are not due to inherent qualities, but that they are the outcome of those external influences which are usually summed up in the term environment. To what extent the thought of man, so far as it is a product of environment, has been affected by the factor of climate will be briefly indicated by a few extracts from various writings in which the subject has been treated.

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[a] See Conduct and the Weather, by Prof. Edwin Grant Dexter.

Buckle has classed the physical agents that have most powerfully influenced the human race under four heads, namely: Climate, food, soil, and the general aspect of nature.[a] In a part of his subsequent study he arrives at the following general conclusions regarding the manner in which these agents have served to regulate thought:

> Wherever man has been able to cope successfully with their influence or where they have been found favorable to his nurture, there will the faculties of his reason assume control of the workings of his imagination; the sense of his own importance will be strengthened with each successive victory over the material manifestations of nature; the gradual growth of his powers will call into being, first, the arts, and then the sciences, and, finally, in arguing from the known to the unknown he will apply to all of the abstract problems of existence those intellectual methods which have so well served the requirements of his daily life. On the other hand, where the forces of nature, hemming him in on all sides, cooperate in opposing innumerable obstacles to his efforts, there will the feelings of terror or wonder be engendered, exciting in his mind an idea of the vague and uncontrollable, thus inflaming the imagination and bringing under its dominion the slower and more deliberate operations of the understanding.

This line of argument brings most naturally to the mind a picture of the orderly march of nature in the temperate zone, in contrast with the prodigal display of energy which is exhibited in those tropical regions where heat and moisture work their fullest effects. It is the comparison, in fact, to which Buckle afterwards resorts, selecting for his purpose Greece and India as examples of climatic contrasts, and choosing the religious beliefs of the two countries in the earlier stages of their development as affording a suitable reflex of the common thought. In addition to the favoring physical peculiarities of the former country, he says that—

> dangers of all kinds were far less numerous than in the tropical civilizations; the climate was more healthy; earthquakes were less frequent, and hurricanes less disastrous.

As a result of this the human mind was less appalled, and consequently less superstitious. It saw in itself an expression of the highest powers, and as a result established analogies between gods and men that clothed the former with all the forms, attributes, pursuits, and tastes of the latter. In India both the circumstances and results were entirely different. Not only were the fixed aspects of nature of a more imposing character, but her active energies also operated on a much grander scale, the climatic conditions producing violent and sudden tempests on the seas, swelling the rivers to impassable torrents by heavy rains, and building up on the land the tangled growth of the impenetrable jungles. All of these influences combined to create a feeling of awe and to establish in the mind of man a sense of his utter insignificance. The demonstrations of the highest powers, so far from being identified with his capabilities, were removed to the utmost degree, and as a result the religion of the people was based on a mythology of terror of the most extravagant kind. Says Buckle:

> In the dogmas of their theology, in the character of their gods, and even in the forms of their temples, we see how the sublime and threatening aspects of the external world have filled the mind of the people with those images of the grand and terrible, which they strive to reproduce in a visible form, and to which they owe the leading peculiarities of their national culture.

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[a] History of Civilization, Vol. 1, Chap. II.

With the progress of history the effects of these external influences, among which climate has always had a place, have remained continually in evidence. In the temperate regions the passing of the centuries has witnessed the increasing dominion of reason over the vagaries of the imagination and the gradual emancipation of the religious beliefs from many gross forms of error. While in most of the tropical countries the intellect is still cowed by the immensity of the forces with which it is confronted, the religious beliefs taking the form of fetish worship among the lowest tribes, and relieved of strange and grotesque features in the higher civilizations only by the engrafting of foreign thought, or else through the uplifting grandeur of those great minds that appear from time to time in every nation. That even these great intellects could not wholly escape the law of environment may be seen in the spirit of fatalism which pervades the teachings of Gotama Buddha, and which finds expression in the kismet of the Mohammedan Turk.

Indeed, evidence may be adduced to prove that Christianity, in common with other great religions, has in its development encountered the potent spell of climatic influence. Renan claims that the climate of Galilee, through its influence on the minds and modes of life of the people, developed in them a nature suitable for the reception of the pure and gentle teachings of the Master. Speaking of the group that gathered on the banks of the lake of Tiberias, he writes:[a]

> The beautiful climate of Galilee rendered their existence a perpetual enjoyment. One can not realize the intoxication of a life which thus glides away under the canopy of heaven; the feelings now gentle, now ardent, produced by this continual contact with nature; the dreams of those starry nights under the infinite expanse of the azure dome. It was during such a night that Jacob, with his head resting on a stone, beheld in the stars the promise of an innumerable posterity and the mysterious ladder reaching from earth to heaven by which the Elohim ascended and descended.

Not only, then, was the climate influential at the very inception of Christianity, but, if we may accept the conclusions of Kingsley, it very materially affected certain after stages of its marvelous growth. In tracing the rapid development of the monastic system he found that, while comparatively little advance was made in interior Europe—

> the mountains and deserts of Egypt were full of Christian men who had fled out of a dying world in the hope of attaining everlasting life.[b]

The inducements there offered for a life of contemplation are afterwards described:

> For, indeed [continues Kingsley], in no northern country can such situation be found for the monastic cell as in those great deserts which stretch from Syria to Arabia, from Arabia to Egypt, and from Egypt to Africa, properly so called. When we think of St. Antony on his mountain, we must not picture to ourselves, unless we, too, have been in the East, such a mountain as we have ever seen. We must picture to ourselves mountains blazing day after day, month after month, beneath the glorious sun and cloudless sky, in an air so invigorating that the Arabs can still support life there upon a few dates each day, and where, as has been said, "man needs there hardly to eat, drink, or sleep, for the act of breathing will give life enough;" an atmosphere of such telescopic clearness as to explain many of the strange stories which have been lately told of Antony's seemingly preternatural powers of vision. * * * The stars leap out, not twinkling, as in our damper climate here, but hanging like balls of white fire in that purple southern night, through which one seems to look beyond the stars into the infinite abyss and toward the throne of God himself.

Without at all involving a question of ultimate truths it may be said with reason that the Bible itself affords many illustrations of climatic influences, through the apposition of meteorological and sacred events, and in the use made of the former in giving point to religious teachings. Noah saw in the deluge the pouring out of divine wrath upon a sinful generation, and knelt before the many colored arch as a symbol of God's forgiveness. Joseph interpreted Pharaoh's dream to signify that for seven long years the monsoon rains would fail to wash the mountain slopes of Abyssinia. In apostrophe and invocation the Psalmist exclaimed:

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[a] Origins of Christianity.

[b] The Hermits.

> He giveth snow like wool: He scattereth the hoar-frost like ashes: He casteth forth His ice like morsels: Who can stand before His cold? Fire and hail: snow and vapors: stormy winds fulfilling His word: Praise ye the Lord!

The winds and the rain figure in the parables of the Saviour. And as the meditations of holy men in all ages have been tinctured by their surroundings, it may be that climatic influences played some part with the dweller on the Isle of Patmos in lending color to the sublime visions of the Apocalypse.

In the writings of the poets we find an equivalent notice and a scarcely less exalted strain. Hugo has given such vivid pictures of elemental strife as to render incarnate the very spirit of the storm. Shelley's poem on the cloud appeals to every reader, not only by its beauty, but also through its accuracy of detail—furnishing, as it does, a classification of cloud forms almost identical with that worked out by scientific methods. Milton's description of the flight of Satan in search of the new-made world and of his passage through Chaos is a literary curiosity in its way; for when he says that—

> Hot, Cold, Moist, and Dry, four champions fierce,
> Strive here for mastery, and to battle bring
> Their embryon atoms—[a]

it is evident that, consciously or unconsciously, he has brought the enemy of mankind almost to the end of his journey, and extended the realms of eldest Night and Chaos into our very atmosphere; for no forecaster of the weather ever found a more perfect description of the never-ending struggle for supremacy that presents itself on every chart prepared for his study.

There is a final class of influences, more often allied to weather than to climate, deserving of notice—a class that plays upon the minor chords of our nature to produce those indefinable emotions which even the dullest of mortals have felt. They find expression in literature when Lowell exclaims, "What so rare as a day in June!" or when George Eliot speaks of the sadness of a summer evening, or, still more defiant of analysis, that spell of Indian summer, enfolding all nature in its silvery haze, which found Huckleberry Finn "lazying around, listening to the stillness."[b]

In all of its phases, then, climate affects man's mental activities; colors all of his thoughts, from his noblest aspirations to his most quiet reveries, and plays upon his soul as on a musical instrument, now rising to the highest pitch and now dying away to the faintest murmur.

These illustrations, relating to a particular feature of climatic influence, have been encountered haphazard in the pleasant pastime of desultory reading, and have but little bearing upon the practical side of our work. Yet it would seem not altogether useless to dwell awhile upon them, for in so doing there comes to us that elevation of mind which the contemplation of any question in its far-reaching results always calls into action; and we are brought more fully to a sense of the importance of our work and of the real dignity of our profession. The first impression of our helplessness to cope with the stern laws of environment gives place to a determination to conquer. We recognize, with Buckle—

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[a] Paradise Lost, Book II.

[b] Compare with Emerson's Nature, where he says: "Even the solitary places do not seem quite lonely."

> that even in those countries where the power of man has reached the highest point, the pressure of nature is still immense; but it diminishes in each succeeding generation, because our increasing knowledge enables us not so much to control nature as to foretell her movements, and thus to obviate many of the evils she would otherwise occasion.

To this increase of knowledge, the Weather Bureau within its proper domains, is devoting its best energies, and the reward due to earnest and systematic effort will not be withheld.

SECTION 3.—FORECASTS AND FORECASTING.

ADDRESS OF THE CHAIRMAN, PROF. E. B. GARRIOTT.

The subject of the third session, "Forecasts and forecasting," is undoubtedly the most important one that can be considered by this convention. In successive annual reports the Chief of the Weather Bureau has announced that the forecasting of severe storms, tropical hurricanes, cold waves, and frosts is the first and most important duty of the Weather Bureau, and that no effort has been spared to strengthen and improve the forecast service wherever and whenever opportunity presented itself. The administrative officers of the Department and of the Bureau recognize that this is the work for which the national weather service was established, and that this is the work for which it is maintained. They recognize that, in relation to this—the first and most important duty of the Weather Bureau—all other kinds and classes of work must necessarily be secondary and subsidiary, and that the value of all other kinds of Weather Bureau work, whether conducted with a view to the improvement of our instrumental equipment or in theoretical and practical investigations and studies of the phenomenon of the atmosphere, is measured by the extent to which they improve or promise to improve the forecasts.

The benefits derived from the forecasts and warnings represent a declared dividend on an investment by the American people of more than $1,000,000 a year. That the investment is a profitable one can not be doubted, and it is safe to say that there has not been a year in the last ten years during which the benefits derived from the warnings have not equaled or exceeded in value many times the annual appropriation, and in several instances the value of property saved by warnings issued in connection with a single storm has equaled the amount appropriated for the maintenance of the service for a number of years. And in addition to the property thus saved the loss of hundreds of human lives has been averted by the storm warnings.

Of scarcely less importance have been the warnings of cold waves and frost. The value of these warnings to tobacco, cotton, fruit, and truck growers has been conspicuous, and it is also recognized on the stock ranges of the west, the northwest, and the southwest, and by merchants and handlers of perishable goods throughout the United

States. The value of the warnings as a means of saving, outright, crops of a fixed value is shown in the citrus fruit districts of the southern tier of States; and in a number of single instances the money value of oranges and orange trees saved in Florida alone by the warnings has aggregated hundreds of thousands of dollars. I think our representatives from Florida, Mr. Mitchell, and from the west Gulf States, Dr. Cline, can testify with regard to the value of the cold-wave and frost warnings to the fruit and trucking interests of the Gulf districts, and Professor McAdie can testify with regard to the value of frost and rain warnings to the fruit growers of California. Numerous instances can be cited in which the value of berries and truck products saved by the cold-wave and frost warnings represent an enormous return on the annual expenditure. In fact, the benefits of the storm, cold-wave, and frost warnings are universally acknowledged by those who have by experience learned their value. And a consideration of the forecasts and warnings forms a part of the business calculations of every up-to-date merchant, vessel owner, vessel master, and agriculturist of the United States, and they are of interest and value to every American citizen.

At no time in the history of the Weather Bureau has the attention been paid that is now being paid to forecasting. With but few exceptions, daily local forecasts are made by officials in charge of Weather Bureau stations throughout the United States. These forecasts are carefully verified, with a view to determining the relative skill of forecasters, and marked skill in forecasting and in discovering aids to forecasting has been announced as the price of promotion.

There appears to be a general misunderstanding as to the manner in which forecasts are verified. In the topics for discussion we have the questions whether forecasts should be verified by a maximum and minimum temperature and whether slight changes in temperature shall be forecast and verified. Verifications made for a station—New York City, for instance—are not compared with verifications made for stations in other parts of the country; they are compared with forecasts made for New York City. You will, perhaps, be surprised to know that there are seven or eight people making forecasts for every station of the Weather Bureau each day. All national forecast officials east of the Rocky Mountains, including those at the central office, make each morning a practice forecast for the entire United States. Each local forecast official prepares each morning a forecast for his own and for an additional or "outer" station. Verifications are made for rain and temperature changes alone; fair-weather forecasts are not verified. In a forecast of rain made, say, this morning (Wednesday) for to-night and Thursday, if no rain falls, two failures are charged against the forecaster. If rain is shown at the morning observation, or at the evening observation, of Thursday, the verification shows one failure and one success. If rain shows at both the morning and evening observations of Thursday, the forecaster is credited with two successes. If rain falls during both periods and no forecast of rain has been made, two failures are noted, and the same process is employed in verifying temperature forecasts. When no temperature is forecast, there is no verification, unless a change to equal or exceed the stationary limit occurs, when a failure is charged. When temperature is forecast, the change must equal or exceed the limit for the season, which during the summer months is six degrees. The only exception to these rules is found in connection with the occurrence of thunderstorms. A thunderstorm, when reported at a station, will verify a rain forecast or a thunderstorm forecast for that station, even if no precipitation is recorded. The only dividend you have in determining verifications of forecasts is your successes. The matter of verifying by maximum and minimum temperatures instead of by the morning and evening temperatures is one which will be open to discussion. This was the method employed a few years ago at the central office. The change was made on the request of the forecast officials.

As the matter of distributing forecasts comes under another session, we will now proceed with the regular programme.

THE RELATION BETWEEN GENERAL AND LOCAL FORECASTS.

By Mr. FERDINAND J. WALZ, *Chicago, Ill.*

As a prelude to a discussion of the relation between the general and local forecasts, it may be well to consider for a moment the question of who may make official forecasts.

Weather Bureau Instructions Nos. 7 and 19, 1896, and No. 136, 1899, give full and final information upon this subject. Under the provisions and limitations of these instructions all section directors and local forecast officials, by reason of their rank, and observers that have been given special authority therefor are permitted to make and issue official forecasts for the station (and vicinity) at which they are serving. These, and only these, are authorized to make local forecasts. The general forecasts are made by officials under special assignment. This presupposes, then, that only those who have sufficient knowledge, training, and experience in forecasting and atmospheric physics have the authority to make official forecasts. And the experience and training can be efficiently acquired only in the active service of the Weather Bureau. The general forecasters are for the most part postgraduate local forecasters and have been selected on account of their superior ability in the local-forecast work and their fitness, through study, research, and long experience, for duty in the larger field.

In a paper to be read before an audience of Weather Bureau officials, it would be superfluous to enter into any details as to what information relative to the weather elements is entered upon a weather map, or what constitutes a weather map, either in the published form furnished to the public or in the special pencil charts used in forecasting. Nor is it necessary for me to enumerate the specialties which attract our attention as experts in the interpretation of the weather charts or to elaborate upon the general rules and laws which govern us in forecasting coming weather events from them. These are our tools of trade with which we presumably are all familiar.

The original weather maps that contain the entries of barometer, temperature, wind direction and velocity, rainfall, and state of the weather, together with the drawn isobars and isotherms and the defined areas of "high" and "low," and which depicts gradients in pressure and gradients in temperature, is the same for the general forecaster as it is for the local forecaster, except that the chart for the former may contain entries from more stations and cover a greater extent of territory. The general forecaster and the local forecaster alike approach these charts along the same pathway of reasoning and base their deductions upon the same controlling phenomena—namely, the areas of high and of low pressure, their gradients and characteristics. The teachings and experience of each tells him that the weather and weather changes experienced from day to day over the territory covered by these charts depend most largely upon these areas, their relative positions, their characteristics, their frequency, and their paths and rate of movement. Each studies and carefully notes the developments and the movements in the atmosphere in the preceding twelve and twenty-four hours as evidenced by these areas, and from the knowledge thus obtained draws his conclusions as to the sequence of weather that will probably follow in the next twelve to thirty-six hours. Up to this point the course of operations and the psychological pathway of the general forecaster and the local forecaster are practically the same. But here begins a parting of the ways.

The general forecaster is interested in and issues not only the forecasts of weather and temperature for large sections of the country, but he is also responsible for the issuing of timely warnings of storms, high winds, frosts, cold waves, heavy snows, and, in fact, of all weather events that are likely to be injurious to agriculture and commerce or that might be destructive to lives and property in his district. He must then weigh well nature's forces as marshaled on the meteorological maps before him and mentally shift these forces to a new field of action for the night and the morrow. He must predetermine not only the new battlefield, but must make an empirical estimate of the results of the conflict in each portion of it. He determines in his mind and to his satisfaction where these cyclonic and anticyclonic areas will be twelve and twenty-four hours hence. What will be their probable path and rate of movement and what their character then—will they gain or lose in energy? Will they increase or diminish in cloud and rain areas? And what portion of his section will be affected? Will the wind shift or change its velocity; and if so, how and when and where? Having satisfied himself as to these, he issues his forecasts accordingly. Hence, his forecasts are, or should be, an expression of his judgment upon these important points, and should be easily read as such by anyone experienced in forecasting or familiar with weather maps. One of our most distinguished forecasters says that he considers a forecast a good one if the line of reasoning pursued by the forecaster in reaching his conclusions is plainly evidenced in the forecast (provided, of course, the reasoning was sound), whether the forecast in this particular instance is verified or not. He considered it a better forecast, even if not verified, than one not showing any valid basis in charted facts, though verified. The latter was pure guess, and forecasts showing valid reasoning would win, in the long run, against guess forecasts at least four out of five times. The local forecaster, then, when he receives the State forecast, has the opinion of the general forecaster upon these all-important factors: probable storm movement and probable storm development. This manifestly should be a decided additional aid to him in determining upon his local prediction.

It is for this reason that local forecasters are prohibited, in Instructions No. 42, 1896, from issuing their forecast (in the absence of special authority to the contrary) until after the receipt of the State forecasts. It is far from the intention of the instructions, however, to restrict the local forecaster or to compel him to conform his forecasts for his vicinity to the State forecast, but, on the contrary, he is at liberty to not only amplify the State forecast, but to express his own opinion in his forecasts, as far as his judgment of the condition warrants, even to differing entirely with the State forecasts.

ADVANTAGES OF THE NATIONAL FORECASTER.

1. (*a*) Fuller reports. (*b*) Telegraphic reports from a greater number of stations and covering a much larger extent of territory.

2. (*a*) Auxiliary charts showing pressure changes in past twelve and in past twenty-four hours and departure from normal. (*b*) Auxiliary charts showing temperature changes in past twelve and in past twenty-four hours, with departures from normal.

3. On account of his great responsibilities, extending over a large area of country, and to the marine interests of the Great Lakes and the Gulf and the Atlantic and the Pacific coasts, the general forecaster must at all times keep in close touch with the entire meteorological situation liable to affect his district. For this purpose he can call for special observations. Also, local observers send him special observations when marked local indications of approaching changes appear or upon the occurrence of any violent meteorological event.

4. Training, study, and experience.

5. General forecasters for the most part devote undivided attention when on forecast duty to forecast work, and when off forecast duty to study of weather data, maps, storm types, etc., and engage in such research and studies as tend to increase knowledge of weather habits and promote weather forecasting.

6. General forecasters make a forecast for verification every day, both when on and off official-forecast duty, for every part of the United States. This keeps them in continuous training and practice and familiarizes them with the general run of conditions for all sections.

DISADVANTAGES OF THE GENERAL FORECASTER.

1. Short time at his disposal and consequent rapidity with which he must make his deductions and reach his conclusions in issuing his forecasts. At the Chicago forecast center, where are issued daily forecasts of weather, temperature, and winds, and special warnings of storms, cold waves, etc., for the Upper lakes and the twelve States of Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota, North Dakota, and Montana, the total time at the disposal of the forecaster for this purpose is about thirty minutes. It is impossible in this short time to do more than express in any but the most general terms the character of the expected weather and the changes for each State or portion of a State.

2. The State forecasts having to be telegraphed to a great many points, must be brief and concise; and that no delay may occur in transmission and receipt, they must be promptly delivered in regular succession to the telegraph operators.

3. Vocabulary for expressing forecasts is limited. Wording of forecasts must conform as far as possible to the words contained in the logotype duplicating outfit.

The local forecaster is concerned with but a single locality and can concentrate his attention, faculties, and facilities in his deductions upon this limited area. He studies the map only in respect to his own location and deliberates upon the dominant features that seem likely to affect his immediate vicinity. He is aided in his conclusion by a personal knowledge of his surroundings, the local topography of the country. If he be a careful observer, he is cognizant of the local aspect of the sky and the changes occurring or which have recently occurred. He makes his forecast two hours or more later than the observation upon which the general forecaster depends and can take advantage of the changes occurring in the interim. The barograph trace sheet often gives a valuable clue. Then he is familiar with local signs and the sequence in which weather changes in his locality occur. All these he has time to consider in arriving at the conclusions expressed in his forecast.

SUGGESTIONS FOR STUDY FOR LOCAL FORECASTERS.

Prevailing wind for fair weather.

Prevailing wind for foul weather.

Local shift of the wind, and the sequence of weather following; the prevailing direction of wind during the twenty-four hours immediately preceding the advance of a storm.

The shift of the wind with the approach of storms, especially for the winter and spring months.

Formulate local rules in regard to temperature changes which will guide in determining the amount of the expected change and the probable limits that will be registered in important thermal events.

The possibilities of frost and the air temperatures at the local and neighboring stations with which light and injurious frosts will occur.

Professor Moore, in his Meteorological Almanac for 1901 (page 39), gives a number of local rules evolved by him while at Milwaukee for the State of Wisconsin. Rules similar to these, or along this line, should be worked out by all local forecasters, and when accomplished should be collected and published as a bulletin of the Weather Bureau.

The experience of the writer at stations where he has made local forecasts has been that a change in temperature at some selected remote station, or a combination of two or three such stations, very often proved an index to the probable change at the local station and gave information fairly reliable upon which to base a prediction (accurate to within a degree or two) of the maximum or minimum temperature—more especially applicable to the latter—likely to be recorded. At Baltimore it was found that the change at Pittsburg, Parkersburg, or Columbus, or a combination of the three, when studied in connection with the departure from the normal at these stations and at Baltimore, very often enabled one to predetermine quite closely the limits of temperature that would occur at Baltimore within the succeeding twenty-four to thirty-six hours. Of course, the probable movement of the "low" or "high" pressure areas, as the case might be, attending marked changes in temperature had to be carefully considered, as the future path of these areas has great influence in modifying the change in temperature at Baltimore subsequent to that already registered at the stations named. In a similar manner a study of the thermal situation at Huron, Bismarck, and Moorhead was found to give a reliable clue to the probable temperatures and the changes that would occur at Davenport during the succeeding twenty-four to thirty-six hours.

At Baltimore, in connection with a detailed study of cyclonic and anticyclonic weather conditions in its bearing upon the climate of Maryland, tables were prepared and published[a] showing the percentage of times rain followed in twelve, twenty-four, thirty-six, and forty-eight hours, respectively, of the time Baltimore was located in every part of a cyclonic or an anticyclonic area. Cyclonic areas having origin in the northwest or over the western plateau region differ considerably in characteristics from those which originate in the Southwest or in the Gulf region; hence the two were treated separately in the tables. These tables were prepared for the different seasons of the year. The application of this study in local forecasting is best shown by an example or two. If on a weather map Baltimore be found located in the NNE. octant and 700 to 1,000 miles from the center of a cyclonic area which had its origin in the Gulf region—that is, a storm is centered over Florida or the eastern Gulf—and the time is December, January, or February, the tables show that in the past such a position occurred 17 times in five years, and was followed 53 per cent by rain beginning within twelve hours, 35 per cent by rain beginning in twenty-four hours, 0 per cent by rain beginning in thirty-six hours. If the storm center were in the same direction, but from 400 to 700 miles distant—that is, in Georgia or South Carolina—the percentages of 15 similar occurrences in the past were 47, 13, 0, respectively; and if from 100 to 400 miles distant, or in Virginia or South Carolina, the percentages of 8 occurrences were 88, 0, 0, respectively.

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[a] Maryland Weather Service, Vol. I, 1899.

Again, if Baltimore be found in the ENE. octant of a storm of like origin and the same time of year and at a distance of 700 to 1,000 miles, or the storm centered in Missouri or the lower Mississippi valley, the percentages of 33 occurrences are 54 per cent in twelve hours, 21 per cent in twenty-four hours, and 6 per cent in thirty-six hours; while if the storm were 400 to 700 miles away—that is, centered in the Ohio Valley or Tennessee—the percentages of 20 occurrences are 100, 0, 0, respectively.

Baltimore, located in the WSW. portion of the anticyclonic area and 100 to 400 miles from the center, November to March, inclusive, is shown by the tables in 10 occurrences to have been followed 70 per cent by rain beginning in twenty-four hours and 40 per cent in 48 hours; but if from 400 to 700 miles distant the percentages fall to 44 in twenty-four hours and 11 in forty-eight hours. On the other hand, if from 700 to 1,000 miles distant, the percentage rapidly increases to 100 for rain beginning in twenty-four hours. These are given only as illustrations suggestive of the possibilities of lines of study the local forecaster may pursue and apply in his forecast work.

The local forecaster, if he is familiar with the local influence of his surroundings and has acquainted himself with local signs and has formulated from his own experience and from recorded data local laws, then, aided by the advance State forecast, should make a higher average in his percentage of verification than the State forecasts applied to his station.

The general forecaster depends entirely upon the charted conditions and charted changes before him, his experience and his knowledge of storm development, characteristics and movement and the general laws of air physics. It is an easy matter to find a map that equally experienced and trustworthy forecasters will differ in judgment upon, and maps appear, all too frequently for the comfort and reputation of the forecaster, from which it is more than difficult to make any accurate and uniform deductions.

Equipped, then, along the lines before suggested, the local forecaster should be well qualified to stand sentinel for his vicinity, and should not hesitate to take issue with the State forecasts, when, in his opinion, the local conditions justify it. He is remiss in his duty to the people he is serving and to the Bureau if he fails to do so. If he differs to advantage, it shows upon his record, and his official reputation as a reliable forecaster expands. On the other hand, if he differs rarely, or never, his reputation as a forecaster suffers, for he is practically making no forecasts upon his own responsibility. But he can not differ to advantage unless he masters the local situation.

Weather Bureau instructions require that all official forecasts be prepared with the purpose in view of thoroughly subserving the public interest, and represent as explicitly as possible the judgment of the forecast official respecting the conditions expected, and they should be so worded.

Local forecasters are especially encouraged to amplify their own and the State forecasts with particular regard to local interests and the occurrence of local events, and to express themselves in such terms and so completely as to give to the public the largest measure of benefit to be derived from the Weather Bureau.

VERIFICATION OF FORECASTS.

In the verification of forecasts at the Central Office and at the forecast centers the State forecasts are taken as a standard, and all local forecasts are verified and compared with them; hence it would not be amiss for me in this paper, which deals with the relation between the two, to enter into somewhat detailed explanation of the methods and forms employed in obtaining verifications, especially as I am not sure that many of those authorized to issue local forecasts are familiar with either the methods or the forms.

The system used at the Chicago center was devised by Prof. Henry J. Cox, and differs considerably from that used at the Central Office, making it essential that the two systems be explained separately.

Central office system of verification.—The State and local forecasts are verified at the central office by stations, and only the stations which telegraph daily reports are used. The forms (or "verification slips," as they are officially designated) employed have headings and subheadings as follows:

Verification slip.

Date of forecasts, ——— ———.

Stations.	Precipitation.				Temperature.			
	Success.		Failure and not forecast.		Success.		Failure and not forecast.	
	State.	Local.	State.	Local.	State.	Local.	State.	Local.
....	....	....	....	....	....	....	....	....

One of these slips is required for each day. Forecasts are verified, that is, entries are made, only with reference to .01 of an inch of rainfall and temperature changes which equal or exceed the stationary limit, except that a thunderstorm forecast or a forecast of rain is verified as a success at a station where thunder is reported, even when no rain occurs.

The verification entries are made on a basis of 10, or rather on a basis of 5, for each twelve-hour period. For example, a forecast of rain for both periods would be verified if rain occurred in both periods as 10 success, while if rain occurred only in one period and not in the other the entries would be 5 success, 5 failure. A forecast of rain for one period and fair for the other would be verified if the rain occurred in the proper period as 1 success, while if rain occurred in the period for which fair is forecast the entry would be 2 failures.

I would here especially call your attention strongly to the fact that a forecast of fair weather counts nothing, even if the forecast proves correct, while, on the other hand, it counts 5 failure for each period it is in error. In other words, a forecast of fair stands the forecaster nothing to win and 5 for each period to lose, while a forecast of rain stands 5 to win and 5 to lose.

In the verification of temperature the stationary limit is 6° from June to September, inclusive; 8° for April, May, October, and November, and 10° for December to March, inclusive. This means that all changes in temperature in twenty-four hours, based upon 8 a. m. to 8 a. m. readings and 8 p. m. to 8 p. m. readings, equaling or exceeding these amounts, occurring in these months, must be predicted, or else the forecast is charged a failure. A forecast for colder or warmer "to-night" is verified from the twenty-four hour changes on the a. m. map following. A forecast colder or warmer for the second period is verified from the twenty-four hour changes on the p. m. map of the succeeding day.

A forecast of warmer, colder, slightly warmer, slightly colder, slowly rising or slowly falling temperature, not so warm, not so cold, etc., for both periods would verify 10 success, provided the 8 a. m. and 8 p. m. maps of next day each showed a temperature change equal to or exceeding the stationary limit, while if only one showed such a change the entries would be 5 failure, 5 success; if neither showed such a change, 10 failure. A forecast of stationary temperature, slight change in temperature, or no forecast of temperature bring no entries if temperature changes less than the stationary limit occur, but 5 failure is marked against each period in which a temperature change equal to or exceeding the stationary limit is reported. As in the case of fair weather prediction, a forecast of stationary temperature stands the forecaster nothing to win and 5 for each period to lose.

A forecast of warmer followed by stationary temperature could be verified as 5 success, 5 failure, or 10 failure.

In the Chicago system of verification, explained later, a prediction of warmer or colder which is followed by a change in temperature in the opposite direction equal to or exceeding the verifying limits would be counted as 10 failure (on a like basis) for each period in error; that is, 5 failure for the predicted change which did not come, and 5 failure for the change which came but was not foretold.

The percentage of verification is obtained by dividing the total of the successes multiplied by 100 by the total successes plus total failures (or $\frac{S \times 100}{S+F}$), the quotient being the per cent of successes.

Each slip, when completed, shows the average percentage of verification for one day of the forecasts made by the general forecaster, and the average percentage of all the local forecasts made by the local forecasters for the same stations.

Chicago system of verification of forecasts.—A form is employed with headings and subheadings as follows:

	State forecast (made at Chicago, Ill.).								Local forecast (Milwaukee, Wis.).							
	Forecast.				No forecast.				Forecast.				No forecast.			
	Rain.		Temperature.		Rain.		Temperature.		Rain.		Temperature.		Rain.		Temperature.	
	1st.	2d.	1st.	2d.	1st.	2d.	1st.	2d.	1st.	2d.	1st.	2d.	1st.	2d.	1st.	2d.
1																
2																
3																
4																
5																
6																

One form is required for each station for each month. As at the central office, predictions of fair weather and of stationary temperature are not considered in the verification. Entries of successes are made in red, and entries of failures in blue. This is best explained by examples. Under the heading "Forecast rain," the letter R is entered in red for the proper period when rain is forecast and 0.01 of an inch or more of precipitation occurs in that period. A blue R is entered when rain is forecast and this amount does not fall.

Also under this heading the thunderstorm (⌈ϟ) symbol in red is entered when the forecast is for thunderstorms, showers or rain, and a thunderstorm is reported from the station but no rain, or only a trace, accompanies it. However, a blue (⌈ϟ) symbol is not entered when thunderstorms are predicted and rain to the amount of 0.01 of an inch or more falls but no thunder is reported. In other words, a forecast of thunderstorms, rain, or showers is verified as a success either by the occurrence of a dry thunderstorm or a fall of 0.01 of an inch or more of rain. Under the heading "No forecast, rain," a blue R is entered for the proper period when the forecast is fair weather and 0.01 of an inch or more of rain falls in that period.

Under the heading "Forecast, temperature," a red C or a red W is entered under the proper period when colder or warmer, as the case may be, is forecast and a temperature change equaling or exceeding the stationary limit occurs, and a blue C or W when the temperature changes are less than that amount.

Under the heading "No forecast, temperature," is entered a blue C or W when a change in the temperature equaling or exceeding the stationary limit occurs which was not forecast.

As previously stated, in case a prediction of colder or warmer is followed by a change equaling or exceeding the stationary limit, but in the wrong direction, a double failure is registered; that is, a blue C (if the forecast was colder) is entered under "Forecasts, temperature," and a blue W under "No forecasts, temperature."

The percentage of verification is obtained, first, by summing up the red entries for the month under rain, and then the blue entries under both rain forecast and rain not forecast. Add all together and divide the sum of the reds multiplied by 100 by the total of all the reds and blues. The quotient thus obtained will be the percentage of successful weather forecasts. Second, divide in same manner the sum of the red entries under temperature multiplied by 100 by the total of the reds and blues, and the quotient will be the percentage of successful temperature forecasts. The percentage for both elements is the mean of the two.

It should here be stated that the Central Office verifications only compose the official record of the forecaster. The Chicago verifications are for comparison and for the information of the official in charge of the district.

The Chicago system of verification has especial merit in that it not only gives a comparable record of the relative accuracy of the general and local forecasts, but is an excellent medium of suggestions tending to a betterment of the forecasts. The character of the forecasts, especially the failures, are clearly shown, and a study of failures is the best means of improvement. Failures of a positive character—that is, forecasts of weather which does not come—are separated from failures of a negative character, or weather happenings not predicted, and thus the relative values of the two are clearly perceived. By close attention to these verifications one soon discovers whether his failures are due to too much or too little prediction of rain, and an investigation of the maps for the causes is suggested. Also, like suggestions are brought out when it is seen that the general and the local forecasts often differ to the advantage of one or the other.

We have all experienced periods in our attempts at weather forecasting when it seemed that the old adage, "All signs fail in dry weather," was never truer, and when, under what would be in ordinary times almost sure rain conditions, we predict rain, the rain storms persistently refuse to materialize. It is then that the blue R's under "Forecast, rain" pile up on the verification sheet. And again we have experienced periods of the opposite kind, when every little "low" that appeared anywhere on the map gave copious and unexpected rains, and even "highs" would give downpours in the most unexpected places: then the blue R's pile up under "Rain, no forecast." Such periods are plainly manifest on the verification sheets, and suggest research for the causes.

Then, too, a study of these sheets proves a sort of open sesame to character reading, and we are, in a measure, able to gauge the prophetic individuality of the forecaster; that is, his predisposition to predict rain or fair weather when conditions on the charts run uncertain. To such a degree is this true that at the Chicago station we are in the habit of classifying certain forecasters as rain men and others as dry-weather men.

Other possibilities of these forecast-verification sheets are the determining whether failures occur more often in the forecast for the first or in the forecast for the second period; whether forecasts are more accurate for night or for day, and where the forecast of longer range can be made with greater accuracy.

I believe from the foregoing that I am justified in suggesting the adoption, if they have not already done so, of some such system of verification as this by all engaged in official forecasting, and a systematic study of the results obtained.

In conclusion, I would call the attention of all local forecasters to the importance of sending cards or maps to the forecast centers in which they are located when their forecast differs from the State forecast.

Instructions No. 120, 1900, directs that all local forecasts be entered daily upon "Form 1069—Met'l" and sent by mail, attached to the local map or bulletin of corresponding date, to the Central Office whether they differ from the State forecasts or not. This does not revoke the instructions contained in circular letter, forecast division, November 6, 1899, which directs that in case a local forecast is made which differs from the State forecast a duplicate copy of "Form 1069—Met'l," containing the differing forecast properly underscored, be mailed to the station of the forecast official in whose district the local office is located.

DISCUSSION.

Mr. **Edward H. Bowie** (Galveston). After hearing the paper by Mr. Walz it would seem that a discussion is hardly necessary, as he has treated all phases thereof in a manner that leaves little to be said. However, because of the importance of the subject, it may not be amiss to lend additional weight to the force of his instructive and valuable remarks.

That the weather conditions over an area of any considerable extent are comparatively local, anyone versed in the science of meteorology is forced to admit.

How difficult and with a much less degree of certainty must it be then to describe the probable weather conditions for the next twenty-four to forty-eight hours for any one place; and even more difficult must it be to attempt to describe the probable conditions for an area such as any one of our large States comprises. That this is recognized by the successive chiefs of the Weather Bureau is shown by the growing latitude given the forecaster, especially the local forecaster, in his efforts to describe from day to day the sequence of weather changes that will occur for any region or locality within the coming twenty-four to forty-eight hours.

The general forecaster has not the time to attempt to describe in detail the probable weather for the period forecast for, and hence has to limit his forecast vocabulary to such expressions as will best describe the general weather conditions in a few words, such as fair, rain, showers, clearing, threatening, colder, warmer, etc., as the expected conditions may call for, and, necessarily, that which will apply to one portion of the State will not be appropriate at all for another portion. It is on the local forecaster, therefore, that the duty devolves to make in detail a forecast of the expected conditions for his limited territory. This is the primary object of the authority bestowed to make local forecasts, and if one fails to use this authority to make such forecasts, provided he is competent to do so, the purpose for which the authority is granted is not attained. Local forecasting is not that part of the State forecast which applies to the vicinity in which the local forecaster's station is located. A child could do this. When authority to make local forecasts is requested the Central Office is led to believe that the applicant has made a study of the local conditions peculiar to his vicinity, and considers himself, by reason of this particular study, competent to forecast. It is in this field that the local forecaster can be of the greatest value, and not in habitually placing his skill against that of the general forecaster in cases when the conditions are clear and definite, and when, owing to the larger number of reports and the various subsidiary charts at the disposal of the district forecaster, he has a great advantage over the local forecaster. It is when cases of extreme doubt arise that the local forecaster is able to supplement the information given in the State forecast and make a prediction of a greater degree of accuracy. These conditions are especially frequent during the summer months, when the types are flat and local causes are potential in causing weather changes.

Mr. Walz has indicated a number of lines along which studies of peculiar local conditions might be followed, and it will be well for each one of us to follow out, if we have not already done so, similar lines of study.

Authority to make local forecasts for a station carries with it a sharing of responsibility with the general forecaster for failures in forecasting and equal credit for success. This responsibility rests on the local forecaster whether or not his work is that of a careful forecaster, one who studies the local conditions and forecasts accordingly, or that of a passive forecaster, one who never differs the local forecast from the State forecast, no matter what the local conditions indicate—or again that of one who habitually differs, in some instances, apparently for no other reason than simply to differ. It is this last kind of work that is the most pernicious form of local forecasting, and such forecasters should have their authority to forecast curtailed or, possibly better, taken from them.

The matter contained in the local forecast should give in detail a description of the probable conditions in words that will convey a definite meaning to the public. During the season of freezing temperature a forecast of the probable minimum temperature for the following night is of great value to shippers of perishable goods, dealers in fruits, brewers, and many others. This forecasting is comparatively easy, and it is the speaker's opinion that during such times the local forecasting of the minimum temperature for the following night should be made obligatory. At Dubuque, Iowa, where the speaker was last stationed, the number of requests during the winter months for this information exceeded that for all other kinds of information. The forecasting of winds at interior stations should receive attention, as by such the public will be helped greatly in understanding the course of reasoning followed in making the forecast.

SHOULD THE VERIFYING CHANGE OF TEMPERATURE BE SMALLER, AND SHOULD NOT THE TERMS "SLIGHTLY WARMER" OR "SLIGHTLY COOLER" BE CREDITED?

By Prof. H. J. Cox, *Chicago, Ill.*

Several years ago, in discussing forecasting and verifications with a prominent official of this Bureau, he made the following statement:

> Good forecasts will invariably attain a high percentage of verification, no matter what rules are used.

Only a short time ago I heard the same official make another statement which bore on the same subject. He said:

> After men have qualified as general and local forecasters and shown that they are able to make good predictions, their forecasts should be exempt from technical verification and they should be encouraged to make the best possible forecasts in the interests of the public, and absolutely without regard to verification.

These two statements deserve thorough consideration at our hands, and may serve as a basis for this discussion.

I have seen many instances of forecasts, excellent from the point of view of the public, obtaining no verification and even a minus quantity. The present rules of verification are probably as good and even better than any that have ever been used previously by the Weather Bureau, yet it seems to me that they are very faulty and should be changed in many important particulars or else rules abolished entirely. Weather predictions are made for the benefit of the public, in the interests of the farmer, the shipper and handler of perishable goods, the iceman, the ice-cream man, and the like. Yet the official, in issuing his forecasts from day to day, often finds himself actually hampered and restricted by the rules of the Bureau. If threatening rain is approaching he must determine whether it will reach a certain point at a certain stated time, either 8 a. m. or 8 p. m.; if before 8 a. m. it is night; if after 8 a. m. it is the morrow; yet this 8 a. m. Washington time is 7 at Chicago, 6 at Denver, and 5 at San Francisco. This time marks the ending of the night in every case, as far as the Weather Bureau verification is concerned; but certainly people the country over have a different idea of night, and do not believe that it begins and ends according to our standard, but that it begins at dark and ends at dawn; even some think that the night forecast ends with midnight. A forecast of rain for the following night is verified, provided .01 of an inch falls between the following 8 p. m. and 8 a. m.; it is of course verified if the rain falls just before the following 8 a. m. Up to that time it is considered night by us, but certainly not by the public. A man may forecast snow flurries and they may occur at frequent intervals, giving him apparent ample verification; yet at the following observation a trace only may be recorded, oftentimes due to rapid evaporation or melting, and another example is offered of a good forecast with a bad verification. According to the present rules of the Bureau, the forecaster who fails to predict rain loses no more if 1 inch falls than if 0.01 of an inch is recorded, and this 0.01 of an inch may in exceptional cases be due to the large personal error of the local observer. Had the forecast been for fair weather, he might not have seen so much. If a forecaster should be so unfortunate as to make a forecast of rain for the wrong period—that is, fair weather for the first and rain for the second, while rain actually occurred in the first period and fair weather in the second—it would be far better for his verification not to predict rain at all, although the forecast might be a good one and be apparently verified. When the farmers are crying and praying for rain, it matters little to them in what period the rain falls, so long as they get it, and the forecast which they consider successful should have a value in the verification.

The forecasts of temperature are verified by the twenty-four hour changes shown on the temperature maps at 8 a. m. and 8 p. m. These verifications and failures are often simply accidental, and do not indicate the proper value of the forecast. In the spring and the summer afternoons thunderstorms create havoc with temperature verifications, and lake and ocean winds are often most important factors in cooling the air toward evening after a warm and distressing day. The public invariably consider the maximum and minimum temperatures in their estimates of warm and cool days. Frequently, although the maximum temperature shows a much higher reading on a certain day than on the day previous, yet the 8 p. m. temperature, through some accidental disturbance or shift of the wind, may show a lower reading than that which prevailed twenty-four hours previous. During the recent hot wave a maximum temperature of 104°—breaking all records—was recorded at St. Paul on July 24. On the previous day a maximum of 100° was reached. On July 23, the first day, the forecast was for "continued warm" over the second day, but a loss was registered against the forecaster because the 8 p. m. reading on the first day was 12° higher than on the second, although the maximum on the second day was 4° higher than on the first. Instances of this kind might be enumerated without number. Again, a forecast of temperature for "to-night," or the first period, is not verified by the temperature prevailing during the night, but by the change noted at 8 o'clock the next morning. In other words, it is simply a prediction of the probable temperature at that hour.

Instructions No. 40 of 1899, provide in regard to temperature verification, that changes equaling or exceeding the stationary limit, which is 6° from June to September, inclusive; 8° from April to November, inclusive; and 10° from December to March, inclusive, will be charged if not forecast; and these limiting changes must be reached in order to obtain verification of the temperature forecasts. I do not know why the stationary limit varies during different seasons of the year unless it is because the changes are generally greater during the winter than in summer. The forecasting of changes in summer is important, because during that season personal comfort and even health are affected by extreme hot weather, and the condition of certain perishable goods varies decidedly, often requiring much attention in order to prevent decay. During the spring and fall in the northern States temperature forecasts are generally of comparatively little importance, but in the winter they assume their greatest value, as a slight fall in the temperature often results in the freezing of goods and in their absolute destruction. Much may be said both for and against the forecasting of slight changes in temperature. Occasionally warm waves gradually develop during the summer time with the rise in temperature from 2° to 6° each day. A few instances have been found where the daily temperature rise over the greater portion of the country was slight and not sufficient to verify forecasts of warmer weather under the present rules, although at the end of three or four days extreme hot weather had overspread the country. While the forecasting of the gradual rise in temperature under such conditions is important, forecasts of cooler weather, after the hot wave has once developed, should be made with the greatest care. I believe it important that under these conditions cooler weather should not be forecast unless the hot wave is about to break, and that predictions of slightly cooler should not, under any circumstances, be made unless it is expected that the temperature will gradually fall from day to day, and ultimately bring on cool weather. During extreme hot weather slight changes are seldom felt. Often, in fact, although the temperature may fall 4° or 6°, personal discomfort intensifies because usually the relative humidity rises daily, thereby increasing the sensible temperature. Again, when humanity is sweltering during a protracted heated spell the mere mention of cooler weather, even though slight, is made much of by the press and public, and disappointment is evident should the temperature not be materially lowered. An unsuccessful forecast of cooler weather is then likely to invite severe criticism. Far better is it that the hot wave should break sooner than anticipated than that false hopes be held out during such a period. People are satisfied with the coming of cooler weather, even though it had not been forecast, but should the break in the hot wave fail to come, forecasts of lower temperature only add to their exasperation and distress.

Predictions of temperature changes are undoubtedly of greater importance in nearly every section of the country during the winter than in any other season of the year. The successful shipment of perishable goods absolutely depends upon the temperature conditions, and it is generally important to know within a few degrees what the minimum is likely to be over a certain area—whether to ship in ordinary cars with no protection, or to use packing or refrigerator cars, or not to ship at all. A cold wave seldom approaches gradually, but usually comes with a rush. Yet after the first fall frequently the temperature drops lower and lower a few degrees from day to day. Often, moreover, the recovery from a cold spell is gradual. It is important to keep the public well informed as to these coming slight changes, as much depends upon them. The successful forecasting of the ensuing temperature during twenty-four hours in the winter season is easy as compared with other seasons, but unless slight changes are anticipated the public is deprived of information which should be in its hands. Several years ago my predecessor in Chicago, Professor Garriott, inaugurated a plan to include in the winter season in his local forecast an estimate of the minimum temperature during the following night. This information has been of great value to many business interests, and all local forecasters are advised to supplement their predictions accordingly. Such an estimate can easily be given in local work, but is most difficult in State forecasting. In my opinion it is important that forecasts of slight temperature changes should be allowed during cold weather and at the approach of hot waves in summer. While the probable local conditions may be estimated quite closely, the present rules do not favor such work in State forecasts. The absence of a temperature forecast now means that the temperature the following day may be as much as 8° or 9° warmer or colder than when the forecast was issued. In other words, at any temperature within a range of 18°. The range of temperature not requiring forecasts should certainly be less when it is considered how much frequently depends upon even slight temperature changes.

I believe that the forecaster who has shown himself competent should be given free rein; that he should not be hampered and restricted by set rules, but that he should be encouraged at all times to make his forecasts in the interests of the public; that if rules of verification must be used, every forecast which is really good should have a full verification. The more stringent the rules under which a forecaster works, the poorer his predictions are likely to be. These rules were primarily made and exact periods designated in order that definite percentages of verification might be determined, that comparisons might be made in the work of general forecasters, and between that of the latter and of local officials. Such a scheme is well enough, ordinarily, for the purposes of technical comparison, but I believe that forecasts would really appear to better advantage without such restrictions. I do not mean to suggest that they be made more indefinite or vague, or that even the plan of using exact periods be abolished, but that every word used in a weather forecast be considered to mean exactly the same as that understood by the public. Should such changes be made, causing the forecaster to feel absolutely free to express his opinion of the coming weather without having in mind technical verification, the forecasts would undoubtedly be much improved, be more easily understood, and be of greater value to all interests.

DISCUSSION.

Mr. E. H. **EMERY** (New York). The subject of temperature changes is one upon which there are many views. He who attempts to establish verifying changes for the various months of the year should have some knowledge of the effect of such changes on the sensations experienced by a community. If such knowledge is not attainable, the best one can do is to derive it from his own experience of the effect of temperature changes on his own sensations. As some persons have a greater tactile sensibility than others, so the sensation of temperature varies with different individuals, the effect in the latter case depending largely upon the amount and character of the clothing worn and upon physical conditions.

Upon what change of temperature a forecast of warmer or cooler should be based is difficult to state. To test the skill of the forecaster, one set of rules is as good as another. But such test should not be the sole object of the rules. If the test of skill can be combined with the art of popular forecasting in such a way as to reach a popular approval, rules would be all that they should be. If a combination of this nature is possible, forecasts will not be without appreciation, especially in cities.

Just what percentage of a community is appreciably affected by a change, in the summer months, of 6° of temperature is not known; neither is it known what percentage is affected by a change of 4°. Again, in the winter months individual ideas on temperature changes vary. You might say that it was colder this morning than yesterday morning. Your neighbor does not agree with you, and he may say that, if anything, it is warmer. A look at the thermometer and you find that between the reading of yesterday morning and that of this morning there is no difference. The comparison might be extended to groups comprising a large number of people.

The effect of temperature changes, depending so largely upon the natural make-up of the individual, mode of living, food and clothing, occupation, and upon various conditions of the atmosphere, will not be the same in all cases. Merely lessening the verifying change of temperature will not result in forecasts becoming more popular. Until some definite information is at hand regarding the effect of different changes of temperature upon a community no advantage is gained by making the verifying change smaller.

The terms "slightly warmer" and "slightly cooler," however, should be employed in temperature forecasting only when such terms would better indicate the popular effect of the change anticipated. At certain temperatures the distinction between the terms "warmer" and "slightly warmer" or "cooler" and "slightly cooler" is often unimportant. On the other hand, at certain high temperatures during the summer months a rise of 6°, the verifying change for warmer in these months, is best indicated by the term "much warmer," and a rise of less than 6° by the term "slightly warmer," while a fall of 10° should be indicated by the term "cooler," and a fall, say, of 6°, by the term "slightly cooler."

If credits are given for changes smaller than those now used for the terms "warmer" and "cooler," temperature forecasting becomes more difficult. Under any code of rules for forecasting a forecaster has about as much as he wants to contend with, provided his main object is to make popular forecasts. In order to make popular forecasts his mind should be entirely free of all thoughts of verification. In consuming a portion of his limited time with the question of a trifling change of temperature he would benefit no one and be apt to overlook some of the very important features of the weather chart.

The terms "slightly warmer" and "slightly cooler" should be credited, but they should be credited in the same way as the terms "warmer" and "cooler," and they should be used in temperature forecasting whenever in the judgment of the forecaster they bear a more fitting relation between conditions existing at the moment and those expected to take place.

Mr. D. CUTHBERTSON (Buffalo). The forecaster very frequently finds the terminology of temperature forecasts too limited to make the predictions satisfactory to himself and to the public, whom he aims to serve. At present a change of 10° is the minimum which would verify a predicted change in temperature for the winter months. While that does not seem a very decided change for that season of the year, a smaller number of degrees is often noticed by the public and should be recognized in forecasting by such terms as "slightly warmer" or "slightly colder." If the verifying changes of temperature were smaller and the terms suggested were credited, greater utility of temperature forecasts would result and there would be greater satisfaction to the public. During the month of June, this year, 11 per cent of the temperature changes that occurred at the stations reporting telegraphically to Buffalo were the verifying limit of 6°. During July, 13 per cent of the temperature changes at the same stations were the 6° limit. At Buffalo this limit occurred nine times during June and sixteen times during July, being 15 and 26 per cent, respectively. For those two months, then, 1 of every 8 temperature forecasts for the different districts was doubtful, and at Buffalo for the latter month 1 of every 4 forecasts was doubtful. It is probable that about one-half of this rather large number of instances, after puzzling the forecasters considerably, resulted in failures. These cases could well have been covered by the terms suggested and certainly with more satisfaction to both forecaster and public.

In this connection, another difficulty presents itself: The temperature change according to the actual thermometric readings, considering tenths, may vary considerably from the change according to the telegraphic report. For example, if the telegraphic report shows a change of 6°, the actual readings, considering tenths, may show as small a change as 4.1° or as large a one as 7.9°, a variation of nearly 4°. On this account, if verified from the telegraphic report, a forecast of "warmer" or "cooler" may be gained when the actual temperature change is but 4.1° and charged as a failure when the change is as much as 5.9°. While, on the other hand, a forecast of "stationary temperature" may be gained with an actual change of 5.9° and at another time lost when the actual change is but 4.1°. In either case "slightly warmer" or "slightly cooler" would have been appropriate and more satisfactory to all concerned.

The forecaster naturally makes his forecast so as to get the highest percentage of verifications. If the temperature is verified by the 8 o'clock readings the forecast is made accordingly. But when the public considers a temperature forecast, it usually has in mind the general thermal conditions for the period mentioned. The public has no knowledge of the rules obtaining in the verification of temperature predictions and rightfully takes for granted that the forecast is made in accordance with its way of thinking. Evidently we have here a condition of things in which a simple statement is expected to apply in two quite different ways. The public reads out of it one meaning, the verifier, according to existing rules, another. Sometimes the forecast holds good for both meanings, sometimes for but one of them. In the latter case, either the public or the forecaster will be disappointed. However, since the forecast is made for the information of the public it would seem to be advisable to make it so as to be of greatest use to the public.

There are circumstances which make the 8 o'clock readings undesirable for verification. To select a particular instant each morning and evening by which to verify predictions as to the thermal conditions for the whole period of twelve or twenty-four hours seems unreasonable to the public and probably unjust to the forecaster. At or near the time of these observations a rapid rise or fall in temperature usually occurs. When this takes place a little earlier one day and later the next, though both days or nights are practically the same in point of temperature, according to the existing rules for verification, a forecast would be called for which, according to the public, would not be realized. Temporary local conditions sometimes cause a similar annoyance. In view of this, my suggestion is to verify, if necessary, the temperature forecasts for a station by the general thermal conditions throughout the period covered by the forecast, as shown by the thermograph trace. I earnestly believe that if the verifying change of temperature were smaller, and such terms as "slightly warmer" and "slightly cooler" were credited, and if, instead of verifying them by the 8 a. m. and 8 p. m. temperature, these and other temperature predictions were verified by the general temperature of the period as shown by the thermograph trace, the forecaster would be able to make better temperature forecasts and the official method of verification would harmonize with the public's estimate of the weather.

Mr. A. J. **Mitchell** (Jacksonville). I ask your courtesy for five minutes, for a reference to the subject discussed in the previous section, as to changing the phraseology of forecasts and incorporating in them the words "slightly warmer" or "slightly cooler." The importance of this depends upon the section and the object sought to be benefited. It is perhaps of little importance in the interior and northern portions of the country, but along the Gulf and South Atlantic coasts it is a matter of serious importance. Suppose the morning observation shows 42° and you expect a fall of about 6°, not enough to specify, but only to say slightly cooler. That will give a temperature of 36° the following morning. Now, I took some comparative observations last winter for my own information. Of course we all know it is cooler on the ground than above, but these observations showed that there are frequently cases when the difference between the temperature of the office and the temperature two or three inches above ground is as much as 6°. The ground temperature, then, will be at least 4° lower than the office temperature, and that will give you a freezing temperature, 32° at least. The importance of this depends upon the object sought to be protected. Take the pineapple in Florida; it is getting into very bad company when it is near the freezing point, or even the temperature of moderate frost. Our forecast may not stipulate that it will be cooler; the forecaster knows that it will be, but it may be deemed a matter of insignificant importance and not to be considered, yet there is the pineapple seriously damaged by a temperature of 38°. The official temperature may not be anything like that, but down in the neighborhood of the pineapple it is almost freezing. The forecast may be correct and at the same time the pineapple and the vegetable growers have lost their crops. We credit the farmer with thinking more along these lines than he does. He has absolute confidence in our wisdom, and relies implicitly on our forecasts. All he does is to mechanically remember; you give the orders and he executes them. If we say cooler, he expects it to be cooler; if slightly cooler, slightly cooler. Let us be specific with him. These conditions are of importance in Florida, though they may be of small consequence elsewhere. Methods of protecting the pineapple crop in Florida by means of cloth or lattice covering have been found necessary, practically throughout the State, although the pineapple can withstand a moderate degree of frost. But to be certain of a paying crop, and a crop under all conditions, protection must be resorted to. Pineapples could not be profitably grown in Florida without the forecasts of the Weather Bureau. In observing warnings the people of Florida act as a unit.

Mr. N. B. **Conger** (Detroit). The forecasting of the minimum temperature for each night, especially during a cold wave, is quite important, and if the maximum temperature forecast were entered as well as the minimum it would serve a good purpose, especially during periods of excessively high temperature. To forecast stationary temperature or slightly warmer temperature would not be exactly right, but the maximum temperature, of a certain degree, would cover exactly the information people desire.

Mr. **Patrick Connor** (Kansas City). I prefer the terms slightly warmer or slightly cooler. I think it is too much like splitting hairs to have to specify the maximum and minimum temperatures, although they should be used in verification of the night and day forecasts. I do not advocate specifying the exact degree.

SHOULD NOT TEMPERATURE FORECASTS BE VERIFIED BY THE READINGS OF MAXIMUM AND MINIMUM THERMOMETERS?

By Prof. A. J. Henry, *Washington, D. C.*

Under the present system the forecaster attempts to make both a qualitative and a quantitative forecast of the temperature changes that are likely to occur within the ensuing twenty-four, thirty-six, and forty-eight hours. He attempts, furthermore, to predict the twelve-hour period in which the changes will occur, whether during the twelve hours ending at 8 a. m. or at 8 p. m. At the morning hour a forecast is made for the ensuing night and the day immediately following. For example, a forecast of higher temperature made from the observations of Monday morning would be cast in the following form: "Warmer to-night and Tuesday." This forecast affirms that it will be warmer during the twelve-hour period extending from 8 p. m. Monday to 8 a. m. Tuesday, and also during the concluding twelve hours of the period, or from 8 a. m. to 8 p. m. Tuesday. The amount of rise in temperature necessary to a technical verification of the forecast varies with the season, being 10° in winter, 8° in spring and autumn, and 6° in summer. The test of the accuracy of the forecast is made by comparing the temperature of the air, as determined by the dry-bulb thermometer at the end of each twelve-hour period (8 a. m. and 8 p. m.), with the temperature at the same moment twenty-four hours previous. If the temperature change equals or exceeds the limiting value for the season it is considered successful. If the forecast is accurate qualitatively but not quantitatively it is deemed a failure, as are also changes not forecast.

Under the system above described the forecaster is most concerned with the changes that are likely to occur at 8 a. m. and 8 p. m., and he naturally brings into play all of his experience and skill *in determining the probable temperature at those two hours.*

The question at issue is, Should not temperature forecasts be verified by the readings of maximum and minimum thermometers, rather than those of the dry thermometer, at 8 a. m. and 8 p. m.? In answering this question, our first effort should be to determine whether the readings of maximum and minimum thermometers more nearly represent the general temperature conditions of the day than do those of the dry thermometer at 8 a. m. and 8 p. m.

It is believed that, as a rule, there is little choice between the 8 a. m. and the minimum readings, so far as showing the daily changes is concerned, and this is especially true west of the one hundredth meridian, where the daily minimum occurs very nearly at the time of the morning observation. As between the maximum reading for the day and the 8 p. m. reading, the former probably represents the character of the day better than the latter. The 8 p. m. reading, during the season of thunderstorms and local showers, does not always represent the true character of the day. A thunderstorm occurring a few minutes before the observation hour, on the warmest day of the season, may lower the temperature 10° to 20°. And thus we may have the curious anomaly of a forecast of cooler weather being successful on the warmest day of the year. On the other hand, we should remember that a thunderstorm or local shower is also liable to occur at the time of maximum temperature and thus spoil a forecast that in all other respects was correct. This much is to be said in favor of the maximum temperature, viz, it falls not far from the middle of the day, and more nearly represents, in the popular mind at least, the character of the day as regards temperature.

In some parts of the country there are very few changes in the daily readings of the maximum or minimum thermometers in the warm season equaling or exceeding 6°. Thus, at Augusta, Ga., during July last, there were but three such changes, while the 8 a. m. and 8 p. m. readings changed by amounts equaling or exceeding 6° as many as seventeen times. These changes were due in almost all cases to the occurrence of local showers in the afternoon. At Washington, D. C., the changes in the maximum and minimum readings were only half as many as in the 8 a. m. and 8 p. m. readings. In the case of Augusta, forecasts verified by the maximum and minimum thermometer readings would have been of greatest service to the public. At Washington, D. C., it would have made little difference to the public which system had been used. In order that some tangible results may flow from this discussion, I would suggest that all forecast officials and others who desire a change from present methods put their views in writing and forward them to the Central Office.

DISCUSSION.

Professor **McAdie.** It is a delightful experience to me to hear several "cries from the heart" here, and I am glad to learn that there are other marksmen in the world who are pretty well convinced that the trouble lies with the target, and that the gun is not as good as it should be, but that the man is all right.

One of the great problems of the Bureau in California is the forecasting of frosts for the citrus fruit growers, and it is of the utmost importance to say colder, even if but 2 degrees colder weather be expected at such critical times, so that there may be no let up on the part of the orchardists in protecting their fruit. It is just at such times that the opinion of the forecaster is most anxiously awaited, and to hamper him by verification requirements is unwise. Often a temperature fall of 2 degrees may occur between 5 a. m. and 7 a. m. The sun rises, say, at 7.26 a. m., and the minimum temperature probably occurs then. The observation is made at 4.40 a. m. Therefore, the change between the 5 a. m. (8 a. m., seventy-fifth meridian) observations might not fairly represent the conditions. Under such conditions (and these do occur) the forecaster must choose between losing his forecast, so far as official verification goes, and saving the fruit, or winning his forecast and letting the orchardists surmise for themselves whether protecting methods should be energetically operated.

With regard to maximum readings when the temperatures are in the neighborhood of 110°, as is the case frequently on summer afternoons in the great valleys of California, the forecast of warmer weather could hardly ever be made and verified under present conditions. Yet the public is greatly interested at such times, and widespread.comment is made should the temperatures exceed those of the previous day by a few degrees.

Both with temperature and rain forecasts, it seems to me, the matter of verification should be given less weight than at present. The method which I prefer is to study my errors. I am less interested in the forecasts which come right and which the public applaud than in those cases where I slip up—where, for example, on a fair-weather type of map rain falls, or where when a forecast of frost is made there occurs a shifting of the wind and a warming up instead of the expected fall.

It seems that the maximum and minimum temperatures afford the only true means of verifying the temperature forecast. Sudden changes are of frequent occurrence during local thunderstorms, and in many instances the maximum temperature is higher, but the current at 8 p. m. is lower than on previous days. While the forecaster may forecast cooler for to-morrow and verify, yet if the maximum temperature is higher than on the previous day the public regards the prediction a failure.

FACILITIES FOR SYSTEMATIC STUDY OF CORRESPONDING WEATHER TYPES.

By Mr. F. H. BRANDENBURG, *Denver, Colo.*

In the summer of 1900 it was my privilege to spend a short time in the forecast division of the Central Office, and in making practice forecasts for the United States I often wished that I had at hand maps of a type similar to the one under consideration from day to day. It is needless to say that in searching for these much time was consumed without satisfactory results, and this caused me to consider seriously the matter of devising some method of classifying maps according to type. Consultation with Professor Garriott encouraged me to undertake the work, and, on my return to station, plans were formulated for a system of ready reference to all weather types shown by the a. m. maps issued by the Central Office during the past ten years.

My purpose in bringing this subject to your attention is not to lay down any procedure for study, but merely to describe facilities which it is believed will prove a valuable aid in quickly refreshing the memory as to the different conditions and types that obtain during any particular month.

The size of the original maps precludes their use, and a small base map of the United States was therefore drawn and printed on half sheets of letter paper, a space being reserved on the left for notations. This space was divided into two columns, at the top of which the words "high" and "low" were printed on one set, while on the other set the words of the heading were reversed. As regards the lines to be reproduced, a sketch of the principal isobars, with the regions of high and low pressure suitably marked, was considered sufficient. The period covered being about ten years, 3,600 or 3,700 maps were sketched. These sketches in turn were duplicated by means of carbon paper, the number of maps for each date depending upon the number of "highs" and "lows" considered valuable in the classification. In some instances one map was sufficient for the set of high areas and one for the set of low areas, and occasionally as many as eight in all were necessary: in general four sufficed. The next step is to outline on each small map the shaded areas shown on the Washington map of the succeeding day, and by shading these areas with a green pencil we avoid interfering with the isobars, which are drawn in red. Thunderstorms were indicated by a small green cross, and the regions visited by temperature changes of 20° were outlined in black. Mention has been made of two columns on each sheet at the left of the map. In the appropriate place note is made of the location of the high and the low areas. Every one of these notations is given first place on some map, and the distribution is made in accordance therewith, every map finding a place in some one of the ten or eleven districts adopted. For example, let us take the high areas for January. A map for each date on which such an area occupied the British Northwest Territory will be found in its appropriate subdivision, and the same is true of any given high area, no matter in what part of the United States it is located. In the subdivisions the maps are arranged according to type, and the total number of dates, as indicated by the number of maps, shows at a glance the prominent features of the pressure distribution for January. Arranged in two small boxes, "highs" in one and "lows" in the other, with cards to indicate the different subdivisions, it is a matter of only a few moments to learn whether any particular type of map is rare or common, and whether pronounced conditions follow.

Since the Washington maps must be referred to for information as to the conditions that obtained more than twenty-four hours after, it is very desirable that they be conveniently arranged. It has been found best to bind three months—say January, 1892, 1893, 1894—in one cover, thus making only three or four books for the entire period. Study of the temperature is facilitated if the changes as shown by the table on the map of the next day are written near the respective stations on the map under consideration. As the number equaling or exceeding the stationary limit is small as a rule, one is well repaid for the work of entering the data, red figures being used to indicate plus and blue to indicate minus changes.

As the current distribution of pressure and whatever important conditions it brought about regarding temperature and rainfall are graphically shown on each small map, I am of the opinion that the use of this system will facilitate the study of all types and necessarily cause a general improvement in the daily forecasts, for no mind is capable of retaining without constant study a clear impression of the weather changes peculiar to each of the twelve months in the different geographical divisions of the United States.

The CHAIRMAN. Mr. Brandenburg has devoted a great deal of time and labor to this subject, and it is only by the expenditure of time and labor that we can make any advance in forecasting or in any other line of work.

HOW TO MAKE THE SYNOPSIS INSTRUCTIVE TO THE PUBLIC.

By Mr. F. P. CHAFFEE, *Montgomery, Ala.*

The daily weather map is the most popular publication of the Bureau and its most constant means of communication with the public. It is the medium through which the Bureau not only conveys its forecasts of coming weather events, but shows in the most graphic way the conditions on which such forecasts are based.

Aside from its value as a public guaranty that the Bureau's deductions are based upon reliable and authentic data, it gives the current weather conditions and the extreme conditions in all sections during the previous twenty-four hours, which information is often of such general importance as to materially influence trade conditions over the entire country. Now, acknowledging the great importance of this publication, it seems that the synopsis—the epitome, as it were, of all the information conveyed and upon which the forecasts are based—is one of the most, if not the most, important of its features.

In a great number of cases those who receive the maps have not the time to study out the details, and a well-couched, concise synopsis is all they desire. Just as one glances over the head lines of the morning paper for such items as he desires to read, so does the hurried business man glance over the synopsis of the weather map for the information which may be of import to his business. Should he find any special mention of unusual conditions over sections in which his interests are involved, then he may look up the detailed reports from such districts. So, in my opinion, the summary or synopsis, which is the very index of the entire weather map, should be most carefully prepared.

Real popular interest in the work of the Bureau practically dates from the time it began the issue of the weather map. Prior to that time the daily reports were bulletined in mere tabulated form, which but crudely showed the geographic distribution of the various conditions as they developed and moved across the country, whereas the weather map, the issue of which began at quite a number of stations in 1887, shows the inception, development, and progress of the great atmospheric disturbances in such a graphic way as to engender an interest in the science of meteorology. Those who received the maps regularly soon began to note the general regularity with which certain weather followed certain conditions; they began to appreciate the difficulties incident to weather forecasting; and the criticisms of the Bureau's work, which prior to this period had been mostly of the facetiousness begotten of ignorance, became more intelligent. It was not long before the regular recipients of the map began to draw their own conclusions, and were thus able to amplify the official forecasts in their application to their own immediate vicinities. Soon the weather map was introduced into the schools, more as a curiosity at first, but now a large number of educational institutions use them to advantage in their daily class work.

If what has been said so far on this subject has tended to substantiate the statement previously made—that the weather map is of great importance to the public in various ways, and that the synopsis of the information on the map is next in importance to the map itself—then every effort should be made and every reasonable latitude allowed in preparing the synopsis in the most interesting style, not only that it may convey the bare facts as shown by the reports; not that it is colder here, warmer there, and that rain or fair weather prevails over certain areas, but that the cause and effect should be woven into the woof of the synopsis, so that each map may in turn present a lesson in meteorology that will appeal to the public.

It is thought that such latitude in the preparation of the synopsis as is here suggested could be safely allowed station officials without danger of their drifting into theoretical speculations which might discredit the Bureau.

Then, again, the treatment of the matter contained in the synopsis varies with the seasons. For instance, during the hot wave and the drought which prevailed over such an extent of country during last

June and July, the excessively high temperatures and their comparison with extremely high temperatures of the past, and any rain that occurred over the districts affected, were the most prominent features in which the public was interested. At other times a cold wave or a killing frost in the great corn and wheat belts of the West may be the central topics for discussion, while, at another time, excessive rains over large portions of the cotton belt, when the great staple of the South is in its most precarious stage, may be subjects for more elaborate treatment than ordinary.

The special bulletins issued to the press by the central office, covering unusually severe storms, floods, etc., often contain information which is of value to the station official in preparing the synopsis.

The charts of maximum and minimum temperatures by decades will be found useful in reference to temperature extremes and their comparison with those of previous years. A new issue of such charts, corrected to date, would, I am sure, be appreciated at map-issuing stations. All local data, such as high winds, excessive rainfalls, heavy snowfalls, first and last killing frosts, and temperature extremes, should be kept up to date and ready for convenient reference in writing up unusual local conditions, for, while the public does not care for a map embodying constant comparisons of current conditions with those of the past, it does appreciate such information when any unusual weather prevails, particularly when such comparisons are deftly woven into the synopsis in a clear and concise style.

In no branch of business, either commercial or governmental, is there a more complete or more accurate and rapid system of collecting reports and disseminating information than that employed by the Weather Bureau in collecting and publishing the results of its twice daily atmospheric surveys. Without considering the limited time allowed for the preparation of the maps, it is not considered presumptuous to say that these publications are, as a whole, most creditable. But so many and such varied interests look to the Bureau for information which is of the most vital importance to them that, in my opinion, every effort should be made to make the daily weather synopsis as instructive and interesting as is consistent with that brevity so necessary to expedition.

It is hoped this matter may meet with that discussion it seems to merit. It is by such discussion and interchange of views that we may be mutually helpful and the great public interests we serve be benefited.

It is thought that in many instances a card publication containing the synopsis and the forecasts would, to a great extent, answer the interests now served by the complete weather map, except to those who desire it for study.

DISCUSSION.

Dr. R. B. **Harkness** (Houghton, Mich.). In entering upon this subject the first fact that occurs to one is that before a weather synopsis as published on a map or bulletin can become an educational factor it must be intelligently and regularly read by those whom we wish to instruct. A primary necessity, then, is to make our synopsis interesting and readable. Our article each day is practically like any news item written for a daily paper, and it will be read only under the same conditions, and should be written with the knowledge that if it be not concise and interesting it will not be read at all and therefore fail of its intended purpose.

It is probable that the majority of persons who have access regularly to a bulletin or map read only the forecast as published and do not try to discover for themselves the laws which have guided the person making the forecast. There is a surprisingly large number of persons, on the other hand, who, upon casual meeting, discuss the morning's map or bulletin in a way that leaves no doubt as to the care with which it is read or the depth of their knowledge of the subject.

As it is necessary to gain a reader before we gain a pupil, it is not out of place to determine what the elements of a good synopsis are and what contributes to making it better and more readable.

A good synopsis, then, is one that in a clear, concise, conservative, and interesting manner, in good English, covers the weather conditions of the country from day to day.

In writing a synopsis day after day we are inclined to fall into a routine method of noting the conditions, i. e., we mention the position of the "highs" and "lows," then the rainfall, then the rise or fall in temperature, then miscellaneous phenomena; in this shape they can be followed only by one who is thoroughly used to them, and to the beginner they convey no hint of the relation they bear to each other, which is one of the prettiest points available for use in our synopsis. The association of falling pressure and southeast winds, rising temperature, and increasing cloudiness, with rain, makes a typical picture to which we like to call attention, and the presence of one suggests the others. Unfortunately, these conditions do not invariably accompany each other, and it is not the typical storms, but the atypic ones, which require study. Mentioning a low area approaching from the Northwest, following it from day to day, with all its attendant phenomena, until it passes off the map, forms one of our best routine synopsis methods.

The instruction given by daily synopses can not, of necessity, make advanced meteorologists, but it can teach the reader to follow the progress of conditions, so that he may seek for himself the reasons for the forecast given, and, later, make his own forecasts. A few attempts at forecasting for himself will probably materially increase his idea of its difficulty and of the efficiency of the Bureau, and it is almost invariably the case that when a man has interested himself in the map and in meteorology and becomes well posted he is thereafter among our stanchest friends and supporters.

Among the classes of persons whom we can best reach the following are the most important: Farmers, grain and produce commissioners, cotton factors, tobacco dealers, railroad men, marine men—lake, sea, and river—the amateur meteorologist, and high school pupils.

The first three classes are men who deal in products which are directly influenced by weather and to whom a knowledge of weather is a distinct business advantage; they go about getting it in the same thorough way that they do information concerning any other branch of their business. The blackboard weather map in the business exchanges is a very good place to gain an idea of the business man's ability to follow weather conditions; the progress of a storm is followed there as closely as the fluctuations in the market, as it is, in fact, frequently itself the cause of such fluctuations. When the attention of these men is called by the synopsis to any regular rule by which the probable direction of a storm can be estimated, there is usually no necessity for repeating it; for example, when the speculator or the horticulturist or agriculturist sees stated as a general fact in the morning's synopsis that frost is probable along and north of an isotherm of 40° the lesson is not lost upon him.

Railroad men as a rule simply accept the Weather Bureau's warnings of a heavy snowfall or rainfall or other unusual conditions and prepare fully for them, and know that "wolf" is very rarely cried without occasion.

Probably the closest students of meteorology we have are the marine men. With them the interest is vital. When the ship captain is in a harbor where a map is issued, his study of the nearest available copy is of the closest. He is rather a specialist in forecasting, as he has practically but two elements, wind and barometer, for one station, his ship, from which to make his forecast. The synopsis can not be used as a method of instruction in his case, but that he is reached in another way by the Bureau is impressed upon one by the number of copies of Professor Garriott's "Wind-barometer table for the Great Lakes" which one sees posted prominently in cabins where only publications of value can gain wall space.

The man who is interested in meteorology as a scientific study for pleasure must not be forgotten. His information is principally gotten from Weather Bureau publications, and his train of thought is in sympathy with that of Weather Bureau trained men, making it a pleasure to write for his benefit, and still more of a pleasure to discuss later with him what you have written.

It is probable that the best results are derived from the synopses which reach high school pupils. In the high schools of nearly every city a critical study is made of every day's map, and the synopsis is read very closely, and any point of instruction contained in it is given due attention. It is very desirable to start the interest of such a class by giving them a talk on the Weather Bureau, the map, means of forecasting, general laws of storms, etc., at the beginning of the year, and having them understand that they are always welcome visitors at the office, and that one is glad to discuss the work of the Bureau with them at any time. Of any given class of readers of the synopsis, the greatest and most far-reaching educational results are probably derived from those which reach high school pupils.

Summary.—A synopsis should be concise, interesting, conservative, accurate.

It should be written bearing in mind the diversified interests and different degrees of meteorological knowledge of its readers.

Each synopsis can not convey a lesson—the lesson must be included as opportunity offers.

Atypical storms can convey a lesson only when the typical storm is known. Hence, for so general a lesson as a synopsis conveys it is probable that the use of a typical storm is best.

Remarks in connection with frosts on the map are of great value, particularly the first in autumn and those occurring late in spring.

In noting frosts early in autumn and late in spring mention of the average date of the earliest and latest, respectively, is of interest.

Knowledge of the amount of snow on the ground in the vicinity of navigable rivers is a necessity in forecasting probable stages.

A purely routine synopsis can hold the interest of only the most enthusiastic reader.

In mentioning any except the best-known cities give the name of its State.

The synopsis is a condensation of the data as entered and to particularize too much is merely to repeat matter entered elsewhere.

Read carefully the synopses written by other men in the Bureau.

Interest and variety are given a synopsis:

By a local note, as "the storm which visited this vicinity yesterday," etc.

By mentioning of especially high or low temperature or barometer or particularly heavy precipitation, etc.

By comparison of existing conditions with previous records.

THE PUBLIC AND THE FORECASTER.

By Mr. Harvey M. Watts, *Philadelphia Press.*

However one may deplore the prevailing but ill-founded belief as to the inaccuracy of the daily forecasts for specific localities, which in some centers has reached a condition of almost universal acceptance, the existence of such a state of things can not be overlooked. The belief, as everyone who is familiar with the substantial accuracy of the Bureau forecasts knows, is the result of careless comparison, and of false perspective, by which all the errors are lumped in a rather formidable phalanx. But the belief being what it is, the question arises whether, utilizing exactly the same data as we have now and pursuing practically the same method of forecasting, public confidence can be restored and the work of the Bureau forecasters for given areas viewed in a new and friendly light. My answer is that, even with the known percentage of error remaining what it is, a more favorable impression can be created by the Bureau forecasts if the forecasters will but recognize certain physico-social conditions that are seemingly overlooked to-day in too many instances.

The unfavorable impression that is more or less prevalent to-day results, obviously, in the first place from the bald unverification of positive forecasts; in the second place (and this often causes more irritation and arouses more criticism than a bald error) from vague, indefinite, negative forecasts, that are silent as to the prospect of change or continuance of a given type of weather that is affecting popular imagination; when, for instance, during a hot spell, the forecast is silent as to temperature while mentioning wind direction and general outlook, and runs somewhat as follows: "For eastern Pennsylvania, fair, southwesterly winds." In the third place, and this seems to me to possess a significance which has never been fully recognized by the general forecasters, it is the bad forecast (bad positively or negatively) that covers the great population centers that destroys confidence in the Bureau forecasts in a way that not only gives the Bureau a poor reputation in that given center, but which, by reason of the discussion of the matter in the public prints that possess a large circulation and a national influence, tends to condition a belief in the inaccuracy of the Bureau forecasts in districts where the results are quite favorable to a belief in the substantial inerrancy of the service. When it is remembered how large a percentage of the total population of the United States is crowded in or near cities, it must be self-evident that in a given instance a forecast might fail to hit the mark for the rural sections of the States of New York and Pennsylvania five times out of six without attracting the attention that one slip out of six would make for the great population centers of which New York City and Philadelphia are the respective foci.

It is the great population centers to which the daily forecast is of immediate moment. It is the public in these centers, which possess a population equal to that of entire States, whose daily social and business affairs are of that complex character that leads them to study and use the daily forecast and to discuss its successes or failures (particularly its failures, the successes being taken for granted) and to pass judgment on the Bureau accordingly. This judgment may be, and often is, capricious and foolish in its unjust severity, as handed down in private circles and in the public prints, but it is a judgment the Bureau must meet and overcome, and it is because the forecast has this pressing physicosocial value in the centers of a maximum population density that the bad forecast is given an intensified effect far above a similar error for a rural district where the inevitable drift of the weather, whether foreknown or not, is taken as a matter of course, and where isolation and the lack of communication prevents that common belief being developed that makes the cities the centers of criticism.[a] For in the cities, by the well-known law of collective suggestion, when once there prevails the belief that forecasts are usually wrong, it is taken up by almost everyone and, spread by the newspapers, creates a general psychological condition of hostility that tends to run the country over, and to discredit the Bureau in a way that is most difficult to counteract.[b]

In meeting the issue that confronts forecasting to-day the most effective thing to do is to attack the problem at the heart. The positive forecast, perhaps, can not be improved under present conditions, but the negative, vague forecast, it seems to me, can be specifically changed for the better, and in the great majority of cases can be avoided altogether. At all events it should be a last resort. Every effort should be concentrated on giving positive forecasts in those particulars that happen to be arousing public attention. And yet many forecasters err in this issue, and the error, a careful examination of the data on given occasions has convinced me, is often without determining reason, so far as meteorological factors go. During a hot wave, for instance, particularly for the great population centers, where its prevalence is a matter of life and death and sickness and checks daily business, everything in the forecast should bend to the question of temperature changes—during a drought or a rainy spell, to any change for the better in the matter of storm phenomena; the frank "no change" being very much more welcome, and, if verified, much more likely to enhance the reputation of the Bureau and forecaster, than the forecasts that seem to avoid the issue on which millions wait with feverish anxiety. Better be definite, even if wrong in the important particular, than continually vague, so that the public prints are forced to declare that the forecasts are "meaningless."

With full knowledge of the difficulties that beset the forecaster, I believe the negative forecast can be vastly improved upon, and particularly for great centers of population. I am absolutely convinced that a marked improvement would set in if the present habit were abandoned by which great population centers are classified, lumped, or tagged on, as it were, to extensive geographical areas, the forecast being made general enough to cover the entire district. Such a forecast may be accurate enough save in the damning particular of the weather of the cities on the periphery of the district. Let me explain. It has happened again and again that the forecast for the district that includes the Philadelphia-New York population area (the largest in the country within the given ellipse which has a major axis of about 100 miles and a minor of about 50, and represents an aggregate of over 5,000,000) may hit the conditions that prevailed on the southern, northern, or western edge of the district, but absolutely miss it for the central or eastern area comprising these two great urban regions. Since it is these city millions who spread the belief as to the success or failure of the daily forecasts, what doth it profit a forecaster to hit it for the wilds of western Virginia and the mountains of western Maryland and miss it for the New York-Philadelphia-Baltimore district? Such a forecast is the most dangerous kind. One of the most striking examples of one of this type is that made for August 1 and 2, 1899, which read as follows:

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[a] Nothing that is said here should be construed as indifference toward the liberal extension of daily forecasts through the rural districts by means of the rural free delivery service of the Post-Office Department or by any other means. On the contrary, such a distribution of forecasts is most commendable, though it is certain when the entire country is supplied with the daily forecast the tendency toward a uniform friendly or unfriendly attitude toward the Weather Bureau's work, now a marked feature of the psychology of city populations, will be repeated in rural districts.

[b] A case in point occurred a few years ago, when, without any well-grounded reason for it, a belief developed in Boston and vicinage that the weather forecasts then issued by the Blue Hill Meteorological Observatory were always right as contrasted with the Government forecasts. Blue Hill never made any such claims. and both the observatory and the Bureau were embarrassed by the belief. In lesser degree and with less reason, there is a tendency on the part of some in New York to view the so-called "Herald" forecasts as more correct than those of the Government Bureau, but the matter will not bear examination.

> Forecast for Tuesday and Wednesday: District of Columbia, Eastern Pennsylvania, New Jersey, Delaware, Maryland, and Virginia, fair Tuesday and Wednesday; variable winds, becoming southerly; continued high temperature for two or three days.

This proved to be bad in every way so far as a large part of the area covered was concerned. It was not true for Philadelphia and vicinage, but I believe was verified by the conditions in northern Virginia. But what if this were the case? Are our great industrial and economic centers to be tied onto undeveloped, sparsely settled areas and forecast for as if by inadvertence? I believe the time has come when such forecasts should be abandoned. To begin with, the signal importance of the population centers should be recognized, so far as the daily forecast goes, and special attention should be given to specific forecasts for these limited but highly important areas. Whether this specificity can be secured by going back to the old method of local forecasting for a given district, of course, with modern improvements, I leave to the more practical men in the Bureau to solve. Much may be said for or against the proposition, but my own view is that the great population centers should be arranged as subdistricts: the forecasts for which should be made from a given office in the district, on the spot as it were, under office conditions that will give the observer and forecaster full opportunity to study the local anomalies; to familiarize himself with the physical surroundings by macroscopical examination of the skies; and to know those facts that are not revealed by a study of mere printed surface data, which will never come to one by mere chamber work, which can only be gained by familiarity with the given locality, and ignorance of which in almost every case is what upsets the general headquarters forecaster and nullifies his forecast.[a]

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[a] Since this was written Professor Moore's announcement that he intends developing independent observatories in certain centers of population, it must be evident, will meet the issue here raised in a striking manner. With such observatories in being, the forecasting for the given areas under discussion in this paper should be susceptible of great improvement, not only in kind but in degree of positiveness and accuracy

Speaking for the Philadelphia district, I have seen the eastern Pennsylvania, Delaware, and Maryland forecast, which covered too wide an area, miss the mark for the city and its vicinage day after day on account of local conditions set up by an oceanic high area, which deflected storm movements from the west so that the city escaped the showers continually predicted by the Washington office. Now, the local effects of this "high" is one of the Philadelphia district's anomalies. Other cities, other population centers, other limited geographical districts, have other anomalies, which can only be ascertained by a continual study of the skies in the large, instrumental facts being supplemented by a general knowledge of the local aerial aspect under given general conditions. I am told by observers and forecast officials that at present they have not the time to make these studies "in the large," but I am sure that the present head of the Bureau, who has done so much to advance the practical work of the Bureau, who has urged the forecaster to get away from the dull and deadening routine, will welcome any plan that solves this problem, and will give the local official all the time he needs if he can show substantial results.

In conclusion, I am convinced if the forecasts for the great population centers be more carefully looked after, if the negative forecasts be reduced to a minimum, that, even without any marked increase in the percentage of accuracy being made, with meteorological knowledge being what it is to-day, the public impression as to the character of the forecasts will be wholly changed, and for the better; confidence will replace skepticism, and the positive successes, and not the failures, will dominate popular imagination.

THE TELEGRAPH AND THE WEATHER SERVICE.

By Mr. J. H. Robinson, *Washington, D. C.*

Our present chief once said that without simultaneous observations and the electric telegraph discoveries in meteorology would be of little value. Judging from this remark he has a high and proper appreciation of the value of the cooperation which has been given the national weather service by telegraph officials.

At our last convention several speakers advised the cultivation by the Weather Bureau people of the good will of the press. No reference was made to the uniformly cordial relations which have existed for the past thirty years between our observers and their closest coworkers, the telegraph officials and operators. Nor does it appear necessary, in the presence of men who have for years maintained close and agreeable business relations with telegraph officials, to dwell upon the importance to themselves and to the service of cultivating and preserving, by all legitimate means, the friendship and good will of men who have, as a class, been so closely identified with the origin and development of the United States weather service. In the early history of the telegraph its officials noted, in making their line tests, the advance over the country of storms. During the period from 1830 to 1840, Espy had demonstrated that areas of rain advanced eastward from the interior of the country to the Atlantic coast, and that severe storms reported in the West and Southwest were usually experienced within a period of one to three days in the Atlantic coast district. In 1850 Mr. George B. Prescott, an employee of one of the telegraph companies then in existence, following in lead of Redfield, Loomis, Espy, and Henry, declared that our Government should establish storm-warning stations along the New England coast and at other points. In the same year Mr. Joseph Brooks requested Mr. Prescott to employ an agent to make daily observations at New York. At the same time observations were also taken at Boston and Portland, Me., and exchanged by telegraph. These reports were found to be of considerable value to steamers plying between New York, Boston, and Portland. Mr. Prescott also advocated the inauguration of a similar system of telegraphic reports upon a larger scale, and stated that, in his opinion, a service of this description would be of great value to shipping and coast property.

In the late sixties the telegraph officials again demonstrated the value of telegraphic reports of weather conditions by furnishing daily reports of weather reported along their lines at the request and expense of the Cincinnati Chamber of Commerce.[a] It is a historical fact that these reports were utilized in the preparation of daily forecasts by Prof. Cleveland Abbe. It will thus be seen that the telegraph performed pioneer service in connection with the present Weather Bureau establishment, and that full credit should be given the telegraph companies for the important part assumed by them in originating our service, and for the more than business interest they have taken in our work since the service became a regularly organized department of the Government. This interest has been shown on many occasions when telegraph communication has been seriously interfered with by storms. At such times they have given us the only wire they had in operation to the exclusion of all other business, and they have almost invariably given us the best service at their command.

The growth of the Weather Bureau system of reports and warnings has been coextensive with the growth of the electric telegraph, and the collection at Washington within the space of an hour of reports of simultaneous observations from an area which covers nearly one-fourth of the surface of the earth, and an equally rapid dissemination of forecasts and warnings, a feat which a few years ago would have been declared impossible of accomplishment, now constitutes a part of the daily routine work of the Bureau. The uniformly splendid work of cooperation of the telegraph companies can not be ascribed to purely business considerations. The telegraph officials have not viewed our work wholly in the light of a business proposition. The many courtesies we have received at their hands have been prompted by a real regard for coworkers in an important and valuable branch of the Governmental service, whose origin and history has been so intimately associated with the great and progressive service which they represent.

IMPORTANCE OF RIVER-STAGE FORECASTS OF THE MISSISSIPPI AND OHIO RIVERS AND TRIBUTARIES IN PERIODS OF LOW WATER.

By Mr. P. H. SMYTH, *Cairo, Ill.*

Before taking up the topic assigned to me I desire to say a few words regarding river forecasts and warnings which are issued in times of flood.

A little over thirty years ago, or before the advent of the Associated Press and the Government river gauge, the newspaper correspondent was the principal agent by which the general public received its river information and its warnings of impending danger from flood.

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[a] See note embodying statement relating to this matter, p. 225.

In those days the larger western newspapers had correspondents at every important place on the rivers. Each correspondent improvised his own river gage, which, as a rule, consisted of a pole or stick driven into the ground. When the time arrived to make a reading the correspondent pulled up his gauge, noted the rise since the preceding observation, then drove it down again at the edge of the water.

Of course the height of the river could not be given, so, in order to convey some idea of the extent of the flood, if it happened to be in flood time, the correspondent would telegraph his paper somewhat in this style: "The river has risen 2 feet during the past twenty-four hours, and is now at the lower end of the old stump on old man Flood's place." As old man Flood's place was well known along the river, and the old stump was a familiar object to rivermen, conjectures at once became rife as to what would be the outcome in the lower valley. Very little attention was given to the amount of the twenty-four-hour change when the rivers were falling.

How different it is to-day! One who watches carefully the daily reports and bulletins issued by the Weather Bureau and published in the daily newspapers can accurately picture the crest of the flood wave as it moves down the valley. He can foretell to a certainty the day and even to within a few hours of the time that the crest will reach any particular place. Mentally he draws his hydrographs, graphically picturing the flood waves passing down the tributary streams, and from data furnished him by the Bureau he accurately calculates the time it will take for these waves to reach the main artery and, approximately, the effect they will have on it.

On receipt of the Weather Bureau warnings, stock, farming implements, grain, and in fact all movable property are transferred to places of known safety, thus reducing to a minimum the destructive effects of the flood. Lumbermen, in addition to protecting their sawmill plants, take advantage of the information by preparing to float timber to their mills. The value of flood warnings is so obvious, even to those who are not directly interested, that to further particularize is unnecessary.

The river forecasts issued by the Weather Bureau in periods of low water in the Mississippi and Ohio rivers and tributaries are, in my opinion, next in importance to river forecasts issued in times of flood. In periods of low water river-stage forecasts are of great benefit to lumbermen, rivermen, and transportation companies.

Lumbermen are busy at all seasons of the year; they must keep their mills supplied with logs at all times, and to be able to do this they must take advantage of every opportunity. They can not wait until the opportunity itself is present, but must anticipate it, and be prepared for it when it comes. How can they do this more practically than by consulting the published reports of the Weather Bureau?

I have had lumbermen say to me that the lumber business has reached such proportions that it would be almost impossible to satisfactorily conduct it now without the daily reports of the Bureau. The movements of lumber barges are governed almost entirely by the information contained in the published reports and the forecasts of future river conditions. As an illustration of the value of river forecasts in times of low water, I cite the following: In the first few days of October, 1898, the lower Tennessee river was at a very low stage; a decided rise occurred in the upper river from the 4th to the 7th, and this information was distributed by mail and telephone throughout the section that was likely to be effected and to persons having interests in that section. A few days later a lumberman wrote to me that he had instructed his logman to start with only about 100,000 feet of logs, but upon receipt of this information he immediately wired him to bring out 175,000 feet. His telegram reached his logman at the last telegraph station on his way to the timber lands. No doubt that many such cases occur which are never reported.

When lumber barges are started down the river to go into some chute to load logs or lumber, the logman is instructed as to the depth he shall load. These instructions are based to a great extent upon the information received from the Weather Bureau. It sometimes occurs that after the barges have been gone two or three days the lumberman is informed that the river will rise to a certain stage by a certain time. Upon receipt of this information he immediately sends word to his logman to load to a greater depth.

The great volume of business done by the dealers in lumber represents a vast amount of capital, and gives employment to thousands of men. The product of about 125 sawmills is handled and distributed from Cairo, and, as fully 75 per cent of this is carried on the rivers, one can readily see how indispensable information pertaining to existing and approaching river conditions is to the lumber interests, particularly so at such times when a rise or fall of 1 foot in the rivers, if not anticipated, would mean a considerable loss or gain.

To river men the river forecasts, in periods of low water, are of interest and value, not so much on account of the information regarding the probable stage, but as regarding the change, whether the river is to rise or fall or to remain stationary. I have reference now more particularly to the great "Father of Waters" below the mouth of the Missouri. From a comparatively clear stream above the mouth of the Missouri the Mississippi becomes a veritable alluvial stream after its junction with that river. "Its bed is a mass of moving and rolling sand, pushed along by the river currents, and to this is being constantly added the soft materials eroded from the banks where the currents press against them." Every rise is followed by a greater or less shifting of the channel line, and "bars" and "reefs" are formed, thus rendering navigation uncertain and at times dangerous. If after a rise the river falls rapidly, insufficient channel depths result; but if the fall is gradual, the river currents cut away the bars and leave a fairly open channel. The longer the cutting process the better the channel, provided, of course, that the river does not get extremely low. It is evident, then, that although fairly good stages may be shown on the river gages, the channel depth may be inadequate for safe navigation, and vice versa. It is for these reasons that the navigator is more interested in information pertaining to probable river changes than he is in river stage forecasts.

Transportation companies would find it very difficult to conduct their river business without the river forecasts and the general river information now furnished them by the Bureau. I have seen passing down the river a tow comprised of 51 barges carrying 1,275,000 bushels of coal. This quantity of coal, if loaded in cars, allowing 30 tons to the car, would require 1,611 cars, or a solid train nearly 10 miles in length. From this statement alone I judge can be formed a very good idea of the extent of river traffic.

In conclusion, I wish to state that I have treated my topic from the standpoint of a river forecaster, and therefore have made flood warnings of first importance. I judge, however, that from a statistician's point of view, records of low water are as valuable as those of floods.

DISCUSSION.

Mr. L. M. **Pindell** (Chattanooga, Tenn.). Low-water forecasting is of almost as much importance as high water or flood stages. On the Tennessee River the boatmen watch for and take advantage of every 2-foot rise. Boats drawing over 3 feet of water, or those which are compelled to tie up when the river reaches and falls below the 3-foot stage, seek the best point for shelter, and whenever a rise of 4 to 6 feet is expected the owners order the engineers to get up steam and be ready to move out on the tide. These boats collect up the freight deposited on the river banks and succeed in making a round trip and sometimes more before the river falls to the 3-foot mark. Shallow-draft boats make weekly trips until the river reaches 1 to 1½ feet. Then they have to be exceedingly careful in passing over shoals and rocks in the channel. Practically speaking, the river men consult the river bulletin and forecast more closely in low water than when the river ranges between 7 and 25 feet. The captains instruct the farmers along the river as to the place where they can put their goods and be above the water. As soon as the low-water season approaches the owners of large vessels send them to the lower river trade to save them from becoming stranded upon the banks in shallow water. I am called on after every rain during the low-water season to know about the height the river will attain or how much water can be expected. Forecasting on the Tennessee River is important at all seasons of the year. When navigation is closed to all boats on account of the river being very low, the boatmen watch for the slightest rise and are ready to steam up to make a trip at the proper time, whether day or night. During low water at and below Knoxville the steamboat masters at Chattanooga, Florence, Riverton, Johnsonville, and Paducah always ask the Chattanooga office to telephone or wire them when the rainfall over the headwaters justifies a boating tide of from 5 to 6 feet in the channel. The Tennessee River Navigation Company invariably start their boats to the Hiwassee and Clinch rivers within twenty-four hours after being notified of the expected rise and the time it will reach the various points.

A few years ago—I think it was in the summer of 1898—Capt. J. F. Beaty, of Paducah, wrote me, asking that I notify him by wire when the conditions would justify a rise of 5 to 6 feet at Florence, Ala.; that he had $40,000 worth of ties on the river bank near Riverton and Florence, and that it would take him five days to reach Florence and two days to load. About six weeks after the receipt of the letter heavy rain occurred over the system, and I wired Captain Beaty. He at once got together his crew, started for Florence, loaded, then telegraphed for conditions. The river was then about stationary, but began falling that day. He returned to Riverton, Ala., with his freight safely, and then wrote the observer a letter of thanks for the timely information.

The Tennesse River, with 29 various tributaries, is navigable for over 1,400 miles. The report of the United States Engineer's Office for 1897 gives 80 boats and 365 barges plying the river—19 boats and 84 barges above Chattanooga, 21 boats and 81 barges between Chattanooga and Decatur, and 40 boats and 200 barges between Decatur and

Paducah. The estimated value of property shipped was $2,693,802.85 above Chattanooga, $4,078,227.39 between Chattanooga and Decatur, and $5,572,408.95 between Decatur and Paducah, or a total valuation of $12,344,439.19. These boats also carried, in 1897, 70,624 passengers.

When this data for the Tennessee River is compared with similar data for the Cumberland, Ohio, and Mississippi rivers, and when it is remembered that more than three-fifths of this traffic is carried during the time when the river ranges from 5 to 15 feet, or moderately low water, the importance of low-water forecasting claims the same attention of the United States Weather Bureau as the high-water forecasting. Prof. Charles C. Adams, of the University of Chicago, Chicago, Ill., used the Tennessee River and flood bulletins during the summer and fall of 1900 (and is now receiving them) to enable him to search the upper tributaries for pearls and other specimens for use in the zoological department of the university.

From expressions given by river men, steamboat men, and log men, I know that the low-water forecasts are of much importance to them, for, during low water, a fall or a rise of a few inches even in the Tennessee River and tributaries, if known in time, means a saving of many dollars to the river traffic. The following occurrence will serve as an apt illustration: During the early part of May, 1897, Maj. Dan C. Kingman, of the United States Engineer Corps, stationed at Chattanooga, Tenn., sent the United States towboat *Colbert* to Knoxville; the boat reached Lenoir City, but owing to low water, with the river still falling, was afraid to proceed. Captain Gray telephoned to Knoxville for river information, which was unfavorable; and the *Colbert* remained at Lenoir City nearly two weeks. Major Kingman stated that had the "low-water forecast" been made at the time, he could have saved the Government hundreds of dollars on this trip.

Capts. J. F. Beaty and James Koger, of Paducah, Ky., visit the Chattanooga office whenever in the city, and have repeatedly stated that the low-water forecast was worth thousands of dollars to the lower river traffic, as they could tell within a few inches how deep they could load their boats and barges, and whether they could successfully make the trip. In a talk with Capt. A. J. Gahagan, treasurer of the Loomis & Hart Manufacturing Company, on August 6, 1901, as to his views of the value of low-water forecasting, he dictated the following to his stenographer:

> This service is very valuable to the mill and river people here. In case of the steamboat people, it enables them to tell in advance of reasonably low water to what extent they can load their boats and whether it is safe to estimate that they can make the return trip. In case of the sawmill and lumber interests here, which is a large industry, this advanced information is really invaluable. It is important that we keep our logs in the river: and if we have advanced information as to the probable fall, it enables us always to keep sufficient force employed in keeping logs in the water to save them from getting out on the bank. As the mill interests here largely keep their logs cabled to the bank above the city, if we have notice in advance of the probable turn in the stage of the water, it enables us to anticipate conditions so as to keep a supply dropped down to our local wharf that we can run on at times when we might not be able to get logs to our landings if we waited until we actually needed them. We unhesitatingly say that the low-water forecast is valuable.

I believe better low-water forecasting could be made if the rainfall observers were authorized to telegraph to the center their rainfall whenever it equalled or exceeded one-half an inch, instead of 1 inch as now, because it frequently happens that the river stations report from 0.50 to 0.90 of an inch for one or two days in succession, then over an inch, then less than an inch, making a total average from 3 to 4 inches, while only one report is received from the rainfall stations, and their total amount for the rain period is unknown until the monthly report is received, when sometimes their totals exceed the totals of the river stations for the same period, but under their instructions could not send the amount by telegraph.

The high stages over the extreme headwaters during May, 1901, which produced great loss and damage over the French Broad and Holston rivers and at Knoxville is a striking example of high water resulting from several daily rainfalls of less than 1 inch. In my opinion, the instructions to the rainfall observers should be changed at once. Another improvement could be made by making Charleston, Tenn., a full river station for the entire year. I receive no information on the south side of the river below Knoxville, Tenn., from May 1 to October 31. The Hiwassee River is a rapid rising and falling stream, and the stage at Charleston is called for during these months by river men and officials from other departments of the United States Government.

I was informed by the river observer that in 1900, when the United States Weather Bureau work closed on April 31, Prof. B. M. Hall, of the United States Geological Survey, Atlanta, Ga., employed him to make daily river readings from May 1 to October 31, at $5 per month. This station if in operation during the low-water months would be of immense importance to the river interests and a great assistance to the forecaster. The improvements by the Government during the past fifteen years have increased the traffic on the Tennessee River, especially in low water, and while the low-water forecast seven years ago was unnecessary, now it is an absolute necessity. It is estimated that within the next two or three years, with proper river appropriations, the improvements now in progress will be completed, the remaining obstructions will be removed, and a low-water stage of 3 feet will be maintained on the Tennessee River during the entire year, making it navigable at all times; then the low-water forecasting will become of greater importance than it is now.

WEATHER FORECASTS AND THE PUBLIC.

By Mr. H. B. Boyer, *Savannah, Ga.*

I am thoroughly satisfied that in the great majority of cases the forecasts are criticised on insufficient grounds, attributable to a misunderstanding or ignorance of the rules of verification by which we are guided in forecasting. This is the point I desire to bring out. The public should be made conversant with what is meant when fair, rain, colder, warmer, cold wave, etc., are forecast. The rules of verification adopted by the Bureau are probably the best that can be devised to meet the present stage of our development; but outside the Bureau these rules are not known, and as each individual has his own conception of what does and what does not verify a forecast, thereon rests the foundation for unfavorable comment. With us a "fair" day means a day without rain, or even with rain if not in excess of a certain small amount, whereas the public, when the term "fair" is used, expect a day not only without rain, but with more or less sunshine; they can not reconcile the words "fair" and "cloudy." I have frequently been prodded with "Is this what you call fair?" on a cloudy day for which "fair" had been forecast. When this has happened I have always taken considerable pains in explaining to my questioner. To be sure, the terms "partly cloudy" and "cloudy" are used, but they are employed in a way descriptive of the expected conditions, and have no influence on the verification. When "partly cloudy" and "cloudy" are used in a forecast, a failure results, in popular opinion, should those particular conditions not appear. As it is with the general weather characteristics, so it is with temperature. Our rules of verification call for different temperature changes in different months. This the public do not know, and the Bureau suffers as a result. I have found that with many a cold wave signifies a decline in temperature to or below freezing, the amount of fall not being considered; therefore a fall in temperature to freezing without a cold-wave warning is a forecast not verified, even should the absolute temperature decrease be but 5° or 10°. Again, I have noted that erroneous ideas as to the daily weather flags are quite common, not so much as to the meaning of the flags as to the period involved. It can be readily perceived how such mistaken beliefs work an injury to the Bureau.

While the first and most important duty of the Weather Bureau is the forecasting of severe storms, tropical hurricanes, cold waves, and frosts, it should be borne in mind that these conditions are comparatively infrequent, whereas the daily weather forecasts, meeting the public eye on every hand and at all times, are assuredly the most potent agency by which a community judges our efficiency. I am of the opinion that the Bureau, in justice to itself and the public, should strenuously persevere along its present educational lines; but while in pursuit of the larger plans it is well that the details be not overlooked, otherwise we must suffer through faulty interpretation. As I understand it, the present campaign of education has for its principal object the recognition of meteorology as a distinct science and its general admission into the school curriculum. Were these objects attained there would result a smoother path for the service, since the public, then looking at the subject intelligently, would see more clearly the end toward which we are working and be more lenient when viewing our 18 per cent of failures. But in the meantime an effort should be made to correct popular errors in respect to the import of the terms used in the several forecasts, or else adjust our rules to popular requirements.

VALUE OF THE DEW POINT IN FORECASTING WEATHER UNDER CERTAIN CONDITIONS.

By Mr. Peter Wood, *Pittsburg, Pa.*

[Read by title.]

One morning in April last, after the observation had been completed. it was noticed that the dew point was much lower than usual, so much so as to attract the writer's attention with more than passing interest.

It was found by comparing the dew point with the air temperature that the latter could contain many grains more to the cubic foot before the dew point would be reached; therefore the temperature of the air must be reduced many degrees before condensation could take place. The Central Office and local forecasts both were for rain, and it was noticed that the rain failed; then it was with renewed interest that the writer began to apply in doubtful cases the dew point as an aid in forecasting.

From the 17th to the 24th of this month for local forecasting it seemed to work very successfully.

To illustrate more precisely, take this morning's observation. The air temperature showed 8.374 grains of water vapor to the cubic foot and the dew point showed 7.480 grains. If the air temperature should drop 3.5 degrees condensation would occur. It did drop 16 degrees in about ten minutes, and 0.95 of an inch of rain was the result. The conditions for this morning were expected to be cooler and less humid, because rain had fallen in the evening and night; but, instead, there was more moisture and at the same time the temperature was expected to drop some, but it did not do so until the excessive moisture had been liberated. Of course this last case would not be of any value for a thirty-six hour forecast, but it showed that the humidity had increased instead of diminishing.

Now, the point is, with a chart of reliable dew-point data and the twenty-four hour changes, would it not be a help to the forecaster?

I know the subject is not new, but that does not necessarily prove it unworthy of further attention.

THE DOUBLE OBSERVATION AS A MEANS OF IMPROVING FORECASTS.

By Mr. LEE A. DENSON, *Meridian, Miss.*

[Read by title.]

After years of close attention to the charts, reviewing disturbances in almost every conceivable position and form, I am led to the conclusion that the forecaster in many instances, no matter how clear his insight may be, fails in his deductions through the lack of clear, exact, precise knowledge of the latest change in the conditions. Is it not the irregularities, the variations in energy, velocity, direction, and general movement of the areas of low and high pressure, the sudden slowing up or the rapid increase of speed that brings consternation to the forecaster, weakening confidence in himself and cutting down the percentage of his nearly perfect deductions under average conditions? If so, how better can we overcome these irregularities than by placing before him complete, precise knowledge through the means of double (6 a. m.–8 a. m., and, if necessary, 6 p. m.–8 p. m.) observations?

This could be accomplished with very little extra labor, now that the stations are well provided with self-recording instruments.

What additional information will it give the forecaster? Well, let us see. With one additional word alone in cipher, carrying pressure and temperature at 6 a. m., will he not be able to observe at a glance the rate of movement compared with the average of the past twelve or twenty-four hours, as the case may be; will he not be able to observe that the center of a disturbance deviates or not from the average path of the past twenty-four hours, and so obtain the latest direction; will he not be able to observe with more exactitude the relation of formation, and will he not be able to observe its waning or increasing energy? All of these latest phases can be graphically pictured on a single chart with colored pencils; red and green, for instance, for the isobars, and yellow and blue for the isotherms, of the 6 a. m. and 8 a. m. readings.

There are several ways in which the information might be enciphered. The following is suggested because it affords a means of sending the pressure change to the nearest hundredth of an inch: Let the word denoting change in pressure since and the temperature at 6 a. m. be the first of the cipher words. Let the first syllable represent change in pressure and the second the temperature. Let the vowels u and a in first syllable show no change and a rise of 0.10, respectively; and, in like manner, e and i for a fall. Now, let the proper consonants, b, d, f, etc., signifying 1, 2, 3, precede these vowels, and we have the first syllable representing each hundredth of change from 0 to 0.19. In the second syllable encipher the 6 a. m. temperature. For example: A rise of 0.05 of an inch and temperature of 70, use the word "Mudrug;" a rise of 0.15 and same temperature, "Maryland;" and likewise, for a fall of 0.05 and same temperature, use the word "Merry," and for a fall of 0.15 and temperature of 70, the word "Miry."

The forecaster has no direct means of getting at the exact variation from the average, and it is for the purpose of developing these irregularities and bringing them clearly to mind that this suggestion is made. It seems to me that we must try some such method if we ever hope to obtain a marked improvement in forecasting.

SUBSTITUTION OF ACETYLENE GAS FOR OIL IN STORM-WARNING LANTERNS.

By Mr. H. W. Richardson, *Duluth.*

[Read by title.]

The recent introduction of high-power lanterns and steel towers marks a distinct epoch in the matter of storm-warning displays, greatly improving that part of the Weather Bureau service. But there is still room for improvement as regards visibility of lights.

At present either oil or electricity is used, depending upon circumstances. Electricity undoubtedly gives the greatest satisfaction, but it is quite costly and not always obtainable.

The distance of visibility depends upon various conditions, viz, the accuracy of the reflecting and the refracting surfaces of the lens, the quality, candlepower, and elevation of light, and the condition of the atmosphere.

A lens in which each prism is ground true and the flame of light placed in the proper focal plane will give a light 50 per cent stronger than with the same candlepower of flame in an ordinary pressed or cast lens. In the strongest lights used by the United States Light-House Establishment on the Great Lakes the burner gives only 163 candlepower, while the beam transmitted by the lens measured over 20,000 candlepower, which shows what an important part the lens plays in this matter. But such powerful lenses are not really practicable for Weather Bureau displays on account of great cost and because of possible interference with range lights, and when a high candlepower is obtained the pressed or cast lens will serve the purpose.

Neither electricity nor oil furnishes a pure white light. The former is, as stated, costly, and the latter, with each increase in candlepower, is accompanied by a corresponding increase in degree of heat. The burners in the new oil lanterns are a trifle over 16 candlepower, and in the old-style lanterns it is probably only half as much.

One of the purest white lights known to science is that obtained from the gas, acetylene. This gas was discovered in the year 1836, but up to the period 1892–1895 its manufacture was costly and restricted to experimental production in laboratories. In the period just mentioned a cheap method of manufacturing calcium carbide was discovered. The combination of this carbide with water decomposes the latter, forming acetylene gas and slaked lime. The cheapness of manufacture has resulted in a wonderful increase in the commercial use of this gas, especially as regards the lighting of residences, places of business, bicycle lamps, etc., the most satisfactory generators being those in which the gas is consumed as rapidly as made.

Interesting experiments have lately been conducted by the United States and the German Governments with acetylene gas as applied to the illumination of light-houses and buoys. The United States Light-House Establishment finds that acetylene is not easily compressible and its use not practicable where it is to be burned for any great length of time without attention, say five to thirty days, particularly in the case of isolated buoys. This defect is on account of the accumulation of unconsumed impurities in the burners, which tend in time to extinguish the light. Such, however, is not the case during twelve to thirty-six hour periods of illumination when the tips or burners can receive attention. This trouble can be almost altogether eliminated by inserting a small amount of absorbent cotton in the gas passage, the cotton acting as a filter. The steadiness of flame depends upon the regularity of flow and evenness of water feed over the surface of the carbide. The process of transformation also heats the gas somewhat, but this would, if anything, be an advantage during cold months, as it would tend to keep the water from freezing. This object can also be accomplished by using a dilute brine in place of clean water, but the use of brine would result in diminishing the intensity of light in proportion to the strength of the brine. Acetylene light also gives off much less heat than ordinary illuminating gas. In a flat-wick oil burner the flame must be nearly four times as large to produce the same candlepower as acetylene, the illuminating power of the latter being more than double that of any other portable light or that of coal gas.

In a lens capable of holding a 52-candlepower lamp the United States Light-House experimenter found that a group of 5 acetylene three-quarter-foot burners gave 320 candlepower, the charge being 6 pounds of carbide, which made about 48 cubic feet of gas, burning nearly thirteen hours. In another experiment, with the same amount of gas, 4 one-half-foot burners gave 32 candlepower each for a period of twenty-four hours. The gas gave off practically no odor nor smoke and very little heat while burning. On the other hand the same 52-candlepower oil lamp caused the lens to become very hot. In the case of the cluster of 5 acetylene burners the lens was only slightly warm.

The cost of commercial carbide, in large quantities, is about 3 cents per pound. One pound of carbide produces a little over 5 cubic feet of gas and will run a 16-candlepower one-quarter-foot burner twenty hours. A 16-candlepower oil burner, in operation twenty hours, using about one-half gill per hour of 12-cent oil, costs 3.43 cents, so it will be seen that the cost of oil is slightly greater than acetylene, the latter also possessing many other advantages.

In experiments conducted by the writer, specially constructed 3-burner and 1-burner lamps were used. Tests as to actual candlepower were not possible at the time. The 3-burner lamp contained a charge of between one-half and two-thirds of a pound of carbide, burning twelve hours at a cost much less than that of electricity and slightly less than oil, producing a very brilliant light. Extra lanterns (white and red, marine) being available, displays were made as near as possible and in conjunction with the new-style lanterns in regular use. It was found that the light of this 3-burner lamp greatly exceeded that of the two 32-candlepower electric globes in the white lantern and slightly exceeded the light given off by the four 32-candlepower globes in the red lantern, comparison being made between the two white lanterns and the two red lanterns. In the same kind of test, using oil and acetylene, the latter gave a vastly superior light.

The 1-burner lamp gave, proportionately, a finer and more satisfactory light than the rather crudely constructed 3-burner lamp, the former being made by a gentleman in Duluth for use on his bicycle. It is not intended that this lamp shall be placed on the market, but the maker has very kindly offered to allow the Weather Bureau (if so desired) to copy the general plan or design free of charge. It contains a number of ingenious and useful features not found in other lamps of this character, greatly increasing its efficiency, giving a beautifully clear, white, penetrating, cheap light that will not jar out or blow out. It is perfectly safe, easily handled, and quickly charged. Such a lamp, enlarged and modified in arrangement, would, it is believed, serve the purposes of the Weather Bureau in the highest sense. It certainly could be used to advantage in place of oil, and to replace electricity where the latter is unusually costly.

The writer is under many obligations to Mr. R. E. Wrege, superintendent, Light-House Service, Milwaukee, for information regarding acetylene as tested by his Bureau, and to Capt. John Flynn, Duluth, for apparatus furnished in connection with experiments.

VERIFICATION OF WEATHER FORECASTS.

By Mr. J. B. **Marbury**, *Atlanta, Ga.*

[Read by title.]

The weather and its changes have been of interest to man from the remotest ages, and there has probably never been a time since his advent upon earth that he has not felt more or less interest in its changes from day to day or season to season. This being the case, there has probably always existed some form of weather forecasting. Prior to the flood there lived wise men who posed as weather prophets, the most noted of whom was, possibly, Noah, who foretold with such wonderful precision the heavy rains which floated his ark for so many long dreary days.

Ancient writers dwelt much on weather phenomena, but their limited knowledge of the subject was based chiefly on the collection of popular weather prognostics with reference to the flight of birds, movement of animals, appearance of the heavens, etc. Certain appearances of the sky were premonitions of certain atmospheric changes; the same was true in relation to the actions of animals. But very little real advance in weather forecasting was made until within the last century. If time permitted, an unbroken chain might be traced from the embryonic stage to the present, showing the gradual evolution from ignorance and superstition to our own age and time, when nearly every civilized nation of the world is maintaining a weather service of some kind and issuing forecasts of the weather of some sort.

The daily prediction of the probable weather conditions is by far the most practical application of the science of the weather. There is scarcely a calling in life that is not to a greater or less degree affected by the atmospheric changes. Commerce on our great waterways is greatly benefited by the storm warnings; perishable goods in transportation are often saved by the warning of a cold wave; the farmer, with his fields of ripening grain, is told when to reap. Much property and many lives are often saved by timely warnings of approaching floods in our important streams. At critical seasons when frost is probable forecasts of its approach are of great benefit to truckers, cotton and tobacco growers. During the period of seeding it is important to know when showers or sunshine are to be expected. These are but a few of the many and varied branches of our Bureau. It therefore seems of paramount importance that to fully meet all requirements the forecaster should have only the public welfare in mind when making his forecasts of the weather to be expected during periods covered by his predictions. He should not allow rules of verification to influence his decision, but say just what the chart seems to reveal to him. He should cast aside the fact that the verification of his forecast is decided by a circle 8 inches in diameter—the rain gage—and remember that there is a vast area to be affected, and while he may not make a high percentage, large property interests may be greatly benefited by the warnings issued to the public. This is especially true during the summer months, when local showers are predicted. It frequently happens that the observer while sitting at his office window can count several showers within a radius of 1 mile of his station, while not a drop falls in his gage. So far as the public is concerned his forecast was correct, while his marking by the official verifier will be zero.

For numerous reasons it seems absolutely necessary that all forecasts should be verified, but it is very difficult to determine just what method of verification gives the most satisfactory results. So far all rules used seem to be more or less defective, and fail to accomplish the desired results. Should we take any special class of predictions and compare them with subsequent conditions on the basis that the forecaster is entitled to 100 per cent whenever the phenomenon predicted follows, and to zero when the subsequent weather fails to coincide with that forecast, we do seem to reach the desired end; but even this does not always give an accurate test as to the ability of the forecaster. For example, there are certain months when the weather is remarkably uniform and settled, the changes very slow and gradual, easy to be foreseen, while at other times changes are frequent and abrupt. There are also sections of our country where the weather repeats itself from day to day for protracted periods. During certain months a constant forecast for fair weather and stationary temperature would be verified 95 per cent, and a prediction of rain would give almost the same result another portion of the year. It would, therefore, certainly not be justice to compare a forecast made under those conditions with those made at points where the weather is as erratic as, say, in New England or in many of the States east of the Mississippi. There are some sections having seasons wet and dry so well defined that about the only failure would be just on the turn from wet to dry, or vice versa. One might predict fair for half the year and rain for the remainder, and make 90 per cent or more, while the same official would probably not make 80 per cent in a different locality.

A forecast for warmer or colder, according to the present method of verification, is far from satisfactory, and is not at all in sympathy with the ideas of the public. Warmer or colder is understood by the layman to mean that the day will be warmer or colder, and not that there will be a certain number of degrees difference in the temperature at the time of two observations taken twenty-four hours apart. It frequently happens that a forecast for warmer is followed by a day with a prevailing temperature lower than on the preceding day, but just at the time of the observation it may be a few degrees higher than at the same hour the preceding day, thus verifying a forecast which is looked upon by the public as a failure. A forecast for warmer should mean that the temperature during the period forecast for will go higher than that on the day the prediction is issued, and the same rule for colder. To more nearly coincide with the popular impression it seems to me advisable to use the readings of the maximum and minimum instruments rather than the temperature at the a. m. or p. m. observations.

FORECASTING FOR RIVERS OF SMALL DRAINAGE AREA, ESPECIALLY THOSE OF NORTH CAROLINA.

By Mr. C. F. VON HERRMANN, *Raleigh, N. C.*

[Read by title.]

Recent developments in the possibilities of the electrical transmission of power have contributed largely to the wonderful industrial progress witnessed during the past decade, and have awakened special interest in water powers, the cheapest and most abundant source of energy. Information of all kinds concerning rivers has been eagerly sought, and investigations in regard to the flow of streams as regulated by varying conditions, the probable elements of danger to machinery and buildings by destructive freshets, or of loss by protracted periods of low water, have been carried on extensively by State or national authorities.

The observation of river stages and the issue of flood warnings became a natural part of the duties of the Weather Bureau from its beginning, and since the reorganization of the river and flood service, in 1893, the importance of the work has greatly increased. While the saving of life and property by successful warnings of dangerous floods is often very large and will always chiefly attract public attention and favorable comment, a truer measure of the value of the river work will be found in the variety of interests constantly served by the information collected and published. This service is fully appreciated by all people whose business is directly connected with rivers, as steamship and transportation companies, levee boards, boatmen and lumbermen, farmers whose crops are liable to injury or destruction by floods, and especially by hydraulic engineers and manufacturers using water power, to whom a knowledge of extreme river stages and daily fluctuations is of the utmost importance.

The work of the river service is now assigned to single officials, who have the sole responsibility for the successful conduct of affairs in their respective districts. The official in charge of a river center must observe the fluctuations of the rivers assigned to him and issue daily forecasts or flood warnings when required, and he thus has the opportunity to carry on valuable investigations into the peculiarities of the rivers within his jurisdiction. The flood service of the Weather Bureau covers all of the larger rivers of the great Mississippi Valley and the Pacific coast region, as well as many smaller streams entering the Atlantic or the Gulf of Mexico. There is accordingly extremely wide dissimilarity in the size and character of the various rivers for which forecasts are made. In a vast river system like that of the Mississippi, or even any of its larger tributaries, where the drainage area is so extensive as to embrace different climates and immense variety in topographical features, the amount of discharge is in great measure independent of local influences, and either remains tolerably uniform or the variations are periodic. In smaller rivers, such as those of the South Atlantic slope, the basins lie largely in a region having uniform features of climate, and the quantity of discharge is regulated by local rainfall.

The problem of successful forecasting for small rivers presents great difficulties, since the physiographic conditions controlling flow must necessarily have a more direct influence over a small than over a large catchment basin. Heavy rains easily become general over a small area, while the topography of the region, the nature of the soil and soil covering, the contour of the stream, etc., even if tending to diminish the run off, can not act quickly enough to materially lessen the violence of the freshets. The rules for flood forecasting are still largely empirical; but the experience gained from a large river will certainly fail if applied to a small one. The specific differences in practical forecasting may be shown by the following illustration: The river forecast official at Cincinnati will hardly find it necessary to take account of the geological formations through which the Ohio has cut its channel, nor of minor features of topography, for the size of the river itself indicates that most of the variations originally resulting from such causes have been obliterated long ago. In general, then, forecasts for definite stages at Cincinnati will depend almost exclusively on the actual stages recorded at river stations above that point, and floods under all but the most exceptional circumstances will not be predicted from excessive rainfall alone. This is true for every important river in the Mississippi Valley. Generally there will be ample time to issue warnings well in advance, since, for instance, the crest of a flood wave requires twenty-three days to pass from Pittsburg to the mouth of the Mississippi.

Very different conditions prevail in the districts of the middle and south Atlantic States. Three gauge stations are located on the Roanoke, the largest river of southern Virginia and North Carolina, which are separated by distances of about 60 miles. But it is possible for the Roanoke to rise from relatively low stages so rapidly that in twenty-four hours the danger lines at all three stations are passed simultaneously.[a] It is necessary in some cases to issue forecasts for a river with only one gauge station on its lower course, which plainly involves still greater difficulties. The official at Raleigh would certainly not dare to predict for the Cape Fear River at Fayetteville, N. C., a rise of 40 feet in forty-eight hours without possessing a thorough familiarity with the peculiar configuration of the river which makes such fluctuations possible.[b] Changes of 30 feet in twenty-four hours are not uncommon in some of the rivers of the south Atlantic coast, and the time required for the flood wave to reach the sea is very short. Under such circumstances river forecasts must depend largely on the precipitation reported and on the estimated rise that may be expected from a given amount, and it is necessary to investigate carefully the influence of all the physiographic and climatic factors in increasing or diminishing the run off in order to achieve a reasonable measure of success.

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[a] This remarkable phenomenon occurred on July 9, 1896, and again on May 23, 1901.

[b] Stages on Cape Fear River at Fayetteville: May 22 (forecast issued), 14 feet; May 23, 48 feet; May 24, 58.5 feet.

For convenience of treatment the physical conditions of the drainage basin will be considered in the following order: 1, geological conditions, such as the influence of geological structure, the permeability or impermeability of rocks, and the peculiarities resulting from different rates of erosion through hard or soft strata; 2, topographical features, the size and shape of the drainage basin, the character of its surface, and the form of the river channel itself; and, lastly, 3, the climatic factors will require somewhat extended examination, such as the influence of pressure, temperature, winds, and rainfall, especially the latter, as modified by topography and location, with reference to the prevailing track of cyclones. Necessarily only brief and general outlines can be presented here, and while the facts apply closely to the rivers of North Carolina, they will probably hold true for most of the streams of the southeastern United States.

I.—GEOLOGICAL CONDITIONS AFFECTING THE FLOW OF RIVERS.

In order to trace the effect of geological structures which modify the flow of rivers, especially during high waters, it will be necessary to sketch quite briefly the general character of the region to which these remarks particularly apply.[a] The States of the Atlantic slope occupy portions of three well-defined geological provinces, known as the coastal plain, the Piedmont plateau, and the Appalachian Mountain region. The Coastal plain borders the Atlantic ocean, extending inland from 100 to 200 miles, and comprises a region recently and but slightly elevated above sea level. It is built up of unconsolidated sands, gravels, and loams, in horizontal layers, through which the rivers flow in tortuous courses to the sounds or directly to the sea. The Piedmont plateau region occupies the territory between the Coastal plain and the mountains, and extends from Alabama to New Jersey. Along its western border the Piedmont plateau is somewhat mountainous, but it is low and rolling near the Coastal plain. This region includes the largest portion of the drainage areas of the Southern rivers. The geological formations here cross the States obliquely, parallel with the mountains, and form a succession of belts of crystalline rocks, sharply upturned, across the edges of which the rivers have cut their channels. After the process of erosion had continued for a long period of time a further elevation of this region took place, increasing the slope, while in the course of ages the soil attained considerable depth, varying from 10 to 100 feet, chiefly by the decomposition of rocks in place. The mountain region comprises the Appalachian system from Alabama to New York, and contains in western North Carolina the highest elevations in the United States east of the Rocky mountains.

The course of a river flowing through these regions may be divided into three parts:[b] (1) The mountain track, where it takes its rise as a mere brook, and, fed by innumerable similar torrents, dashes rapidly down the steep sides of the mountains in endless cascades and growing every moment in volume until it enters lower ground. (2) The valley track, where, now flowing through lower hills or undulations, the stream is found at one time in a wide, fertile valley, then in a narrow gorge, perhaps falling into rapids favorable for water powers or expanding into broader channels. Here it receives the largest tributaries and assumes the most varied aspect. (3) The plain track, where the river finally emerges upon broad, low plains, probably in great part composed of alluvial formations deposited by its own waters. Here, in a winding, sluggish course it approaches the sea through tracks of flat meadow or marsh, and finally, amid banks of mud and sand, passes into the great ocean.

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[a] For details see Bulletin No. 8, North Carolina geological survey, 1899.

[b] Modified after Geike, Archibald: Text-Book of Geology, 3d edition, p. 375.

It is not possible in a brief space to discuss all the influences of geological formations which are of economic importance; indeed, many of these are too intricate to be estimated practically. Minor geological structures chiefly control the flow of underground waters, and thus become very effective at low stages, replenishing springs and keeping up the supply of water in rivers during prolonged drought. It will be sufficient to point out a few of the grosser features which have been found to require consideration in practical river forecasting:

1. The natural boundary between the Piedmont plateau and the coastal plain is formed by the "fall line," which extends from Richmond, Va., to Macon, Ga. Here is found an outcrop of hard, crystalline schists, more difficult to erode than the strata on either side. The elevation of the fall line above sea level, which is nearly zero at Richmond, varies from 26 feet on the Roanoke at Weldon to 250 feet on the Ocmulgee at Macon. The consequence of this formation is that the rivers have eroded much wider and deeper channels above the fall line, over which they flow in rapids or through narrow gorges, where generally the lower river gages are located. For many rivers the effect of this characteristic geological structure is of the greatest importance. Obviously, during a flood an immense volume of water must collect in the wide and deep channel above the natural barrier at the fall line, which can only escape slowly through the narrow gorge described. The Cape Fear River in Harnett County during high water is several miles wide at many places, while at Fayetteville the entire mass of water must flow through a channel from 150 to 200 feet wide and 60 to 100 feet deep before it can spread out over the low region of the coastal plain. A knowledge of this feature removes the natural surprise one first experiences in finding a river less than 300 miles long with a range of 60 feet so far down in its lower course.

2. The permeability or impermeability of the deeper rocks underlying the soil, as well as the depth and porosity of the soil itself, which will be treated later, have a marked influence on the flow of streams and require the consideration of the student of hydrographic conditions. It is impossible to give general facts, since the subject requires investigation for each river basin, and a few examples of this phase of geological structure must suffice. The chief tributaries of the Cape Fear, the Haw and Deep rivers, flow in Chatham County through a slaty, broken region, thinly covered with soil, which sheds water very rapidly. During summer drought the smaller tributaries in this vicinity become almost dry, indicating by the absence of underground drainage and springs the impermeability of the surface rocks. It has been found that heavy rains between Moncure and Chapel Hill, N. C., increase the suddenness and the range of the freshets in the Cape Fear.

On the other hand, below the fall line, and sometimes extending above it, is found a belt of sand some 30 or 40 miles wide and of varying thickness, sometimes reaching 110 feet, which is generally well covered with forests of long-leaf pine. The tributaries flowing through this region, notably Rockfish Creek, are characterized by a remarkable uniformity of flow. Sand absorbs water almost like a sponge and gives it up gradually; the water absorbed is largely removed from the influence of temperature, evaporation is diminished, and the difference in effect between summer and winter rains disappears. Lumber River, which merges into the Little Pedee in South Carolina, flows entirely through a sandy region of this kind. The rise in the Lumber River measured on the gauge at Fairbluff, N. C., does not exceed 1½ feet in twenty-four hours, and it requires six days for the wave crest to pass from the headwaters to the Great Pedee a few miles above Port Harrelson, S. C.[a]

3. Lakes and other natural storage reservoirs evidently regulate the drainage of the area below their outflow and diminish the danger of floods, and their absence operates unfavorably on the constancy of streams. The latter condition obtains quite generally in the Southern States, though probably counterbalanced somewhat by the extensive forest covering still remaining. In some cases the low elevation of the flood plain and the great width of the river will cause many miles of lowlands to be submerged at comparatively low stages, the accumulated water acting somewhat as a natural reservoir. This feature is characteristic of the Santee, in South Carolina, which requires exceptionally heavy rainfall at upper stations to cause an elevation of the stream of 1 foot in twenty-four hours. However, where the contour of the river is such that the large volume of water must seek its way to the sea through a narrow pass, the duration and danger of floods is immensely increased, as already mentioned.

These illustrations are sufficient to show that the geological structure of the ground, as well as meteorological conditions, as cause of floods, merit the careful attention of the river forecast official.

II.—INFLUENCE OF TOPOGRAPHIC FEATURES.

1. The most important feature of topography, resulting from the original upheaval of the Appalachian chain and subsequent erosion, is the slope or gradient of the land surface, which determines the rate of progress of the flood wave and the time available for the issue of warnings and the removal of property from danger. The steeper the slope the more rapidly does the water of the tributaries enter the main stream and the greater becomes the rate of advance of the flood. The declivity of a basin is usually ascertained by dividing the elevation above sea level of the highest point in the watershed by the length of the river, but more useful results would be obtained by calculating the slope for each portion of the river track. The south Atlantic rivers mostly have a very considerable fall, exceeding in many cases that of the entire Mississippi from its sources to the Gulf, though few of these rivers exceed 300 miles in length. The angle of inclination is greatest, of course, in the mountain track. Western North Carolina is noted for its numerous and beautiful waterfalls. In the valley tract—Piedmont plateau—the gradient of the land surface is still quite large and exceeds that of a navigable stream. It varies from 3½ feet in central North Carolina to over 6 feet per mile farther south. The Piedmont

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[a] Weather Bureau Bulletin No. 17, p. 60.

plateau is the region of most available water power and is the home of the manufacturing industries of the South. In the low region of the coastal plain the slope scarcely exceeds 1 to 2 feet to the mile, and the rise of the river during floods diminishes to a few feet.

2. The character of the surface of the catchment basin acts in many different ways on the disposal of the precipitation falling upon it. A shallow soil, overlying an impervious substratum, promotes drainage and prevents the storage of water. A deep, porous soil absorbs water, lessens evaporation, and conserves the water supply while materially diminishing the rapidity with which a given rainfall enters the river or reaches the sea. It is this storage of water by soil and rocks which prevents a river from drying up completely during every summer drought. A clayey soil, while itself able to contain more water than a sandy loam, if saturated, offers great resistance to the entrance of water and increases the run-off. Furthermore, if a river has not cut down its bed to the underlying rock there may be considerable percolation through subterranean fissures.

The soil also acts quite differently in disposing of a heavy rainfall if the season has previously been very dry or very wet; that is, upon the elevation of the ground water depends the proportion of run-off, since the tendency is first to restore the normal elevation of underground water surfaces. The influence of the texture of the soil as modified by tillage will be referred to below.

3. Of the soil covering the two main factors are forests and cultivated land. The action of forests is very complicated, and notwithstanding much study devoted to the subject it is not yet well understood. Excluding some cases where peculiar local conditions obtain, it appears probable that forests have no power to increase the rainfall and their destruction will not diminish it. Forests act entirely as regulators of flow by diminishing the speed with which the raindrops reach the ground and by increasing subdrainage through the removal of ground water by transpiration, in both ways diminishing the quantity of water flowing directly to the streams, especially during summer, though evergreen forests accomplish the same thing in winter. The removal of a forest will not cause more frequent freshets, but will intensify those that do occur, and then only when the deforested area remains untilled. Incidentally the roots of trees and shrubs bind the soil together and prevent the washing of the land into gullies by every heavy rain.

Forests lessen evaporation in the shade of their foliage by reason of diminished insolation, higher humidity, and interrupted wind movement, but at the same time the amount of vapor which they give to the air by transpiration is very large. A forest of oaks will consume more than a quarter of the annual rainfall during the growing season. The vapor thus transpired is lifted from the ground waters which, under similar circumstances, will be found lower under a forest than under cultivated fields. To this extent, therefore, forests do not conserve the supply of moisture, but consume it, as proved by the fact that crops can not be grown successfully near rows of trees.

4. The soil of a well-tilled field, especially where deep or subsoil plowing is practiced, as regards texture is in condition to absorb a large amount of rainfall. When the surface is plowed shortly after a rain the capillary tubes are broken and evaporation prevented by the earth mulch formed. The action of cultivated fields is so marked that the effect must be estimated and allowed for, as it accounts to a much larger extent than usually supposed for the difference in causing floods

of a given rainfall in summer and winter, though temperature here plays the important rôle.

If possible, therefore, for every river basin the extent of the forest covering, the amount of cultivated land, and the proportion of deforested area that remains unimproved should be accurately known and mapped. In the South Atlantic States it is probable that forests still occupy from 50 to 70 per cent of the total area.

III.—CLIMATIC OR METEOROLOGICAL CONDITIONS.

Some knowledge of meteorology and ability to make weather predictions are prerequisites to success in river forecasting. Rivers are the product of the normal rainfall, floods of an excess of the normal, and in considering the influence of the meteorological factors, the element of precipitation and the causes which modify or control it must receive the largest share of attention. For the purpose of a complete view of the subject, however, it it desirable to take some account of the other elements of pressure, temperature, and wind, although it is difficult to estimate their effect for practical purposes. It is not intended to give specific data in regard to climate beyond what is essential for a general outline.

1. *Pressure.*—It is said that barometric changes exert an influence on the level of ground waters, as well as upon the rate of discharge of springs. Diminished pressure causes a rise in the water level in wells and increases the flow of springs.[a]

2. *Temperature.*—Temperature acts upon the water supply of rivers and the manner in which the rainfall reaches them in two ways, by its influence on evaporation, and, when below 32° F., by rendering the soil impervious by freezing; the one cause diminishing, the other greatly facilitating the run-off. Since the capacity of space for water vapor is greater the higher the temperature, evaporation increases with insolation, and is largest in summer and least in winter, but varies also with the relative amount of land and water surface, and on the character of the soil and the vegetation covering it. Measurements of the annual evaporation for a given region are important. The annual evaporation for the south Atlantic states averages approximately 40 inches, as determined by experiments made with a Piche evaporometer in the ordinary instrument shelter, a figure probably too high to represent natural conditions. Assuming that a certain portion of the rainfall for each month is discharged by a stream, then the amount actually so discharged will vary on account of evaporation from 20 or 30 per cent in summer to 70 to 80 per cent in winter. The flow of a river decreases as the temperature rises, and generally so, notwithstanding a larger rainfall during the summer months in the region under discussion.

Frozen ground is very impervious to water, and the run-off in winter is rapid and complete. However, in the South the ground is so rarely frozen for any great length of time even in midwinter that this condition demands less attention than is necessary in the North.

The freezing of the rivers themselves and the formation of ice gorges which frequently become the cause of dangerous floods in colder regions are so rare here that they may be said never to constitute a factor in the problem. Ice gorges form only in the smaller rivers of the mountain section. During the severe winters of 1857, 1886, 1893, and 1895, however, many of the rivers and even the sounds of North Carolina were frozen with ice a few inches thick for brief periods.

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[a] Weather Bureau Bulletin No. 5.

3. *Winds.*—As compared with quiet air, brisk wind movement increases evaporation very greatly. At a velocity of 5 miles the evaporation from a Piche evaporometer was two times that from one in quiet air, and at 30 miles it was six times as much.[a] Winds from the westerly quadrants are more effective than those from the east, on account of their lower dew-point. In some instances on-shore winds during the passage of tropical storms have piled up high tides in estuaries at the moment of flood stages in the rivers with disastrous results. The rain-bearing winds on the south Atlantic slope are those from the south, east, and northeast. On the eastern and southern slopes of the Blue Ridge mountains very heavy precipitation has occurred apparently entirely as the result of winds blowing directly against the mountains, forcing upward masses of vapor-laden air from the ocean and producing condensation in accordance with well-known laws. A remarkable instance of this kind occurred in western North Carolina September, 1898, causing a tremendous downpour of water over the upper basins of the Yadkin and Catawba rivers.

IV.—PRECIPITATION.

In regard to the most important element of all, precipitation, the topics requiring consideration are the distribution throughout the year as shown by the monthly normals, the frequency and duration of excessive rains, the storage of unmelted snow during winter, and, lastly, the special types of weather most favorable for heavy rains.

The south Atlantic States belong to that part of the United States having the largest precipitation, the center of this region of precipitation lying near the mouth of the Mississippi River. The annual is least in Virginia (41 inches) and increases to southern Alabama. North Carolina has the very large annual of 52 inches. Throughout the entire section a larger annual rainfall is found along the coast and in the mountain region than over the Piedmont plateau. There are localities on the southern slope of the Blue Ridge which have an annual not exceeded anywhere in the United States except on the coast of Washington or Oregon. At some points an annual precipitation exceeding 100 inches has been measured.

The abundant and relative uniformity in distribution of the rainfall throughout the year should indicate a steady supply of water in the rivers and the possibility of floods at any season of the year. But in fact the flow of rivers in this region is extremely variable and the freshets frequent and violent, showing the necessity of accurate investigation of all the features of discharge. The greatest monthly rainfall occurs in July and August, and the least in October, with a secondary minimum in April. The rivers of the entire region, however, maintain their highest average stages in February and March, and decline during the latter half of the year, attaining the minimum flow in September.

In respect to the frequency of heavy rains the southern States rank very high. Excessive rains of 6 inches in twenty-four hours have occurred at one or more stations in North Carolina in every month of the year. There seems to be no law in the distribution of excessive rainfalls, though usually they appear to have the nature of local cloudbursts within general heavy rain areas. Of more importance than the intensity of the rainfall is the question whether the rain is general over the entire catchment basin or is due to local convectional currents. Everyone is familiar with the difference in this regard between winter and summer rains, the latter consisting largely of local thunderstorms; and it is then extremely important to know whether rainfall is general in character, which can only be done by keeping close watch of the daily weather maps.

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[a] Monthly Weather Review, September, 1888.

The storage of unmelted snow in the Appalachian mountain region south of Virginia is usually so small that melting snow never constitutes a factor in causing floods. The average snowfall south of Virginia does not reach 6 inches at the highest elevations; and periods of mild weather in winter are so frequent that snow rarely remains unmelted for more than a week at a time. There are therefore no spring floods, as such, in any of the rivers of the South. In February, 1899, with the ground frozen and covered with unmelted snow to an average depth of 15 inches in central and eastern North Carolina, a moderate rainfall and thaw caused dangerous floods in the Cape Fear, but such an occurrence takes place perhaps once in a quarter of a century.

The early recognition of the approach of the type of storm most favorable for the production of general and heavy rains over a river district will forewarn the forecast official and enable him to anticipate its probable consequences. The south Atlantic States are not within the regular track of storms, but the southward movement of the prevailing track in late winter and early spring brings the region under the influence of storms at the season of the year when most other causes contribute to make the run-off of rivers greatest. In general the heaviest rainfall is associated with depressions which move from the west Gulf coast around the lower end of the Allegheny mountains before curving northward. The actual depth of the barometric depression is not its most important feature, but the rate of movement. Therefore, floods are more probable when such a storm is opposed in its forward motion by the presence of an area of high barometer over the north Atlantic States. Frequently the most disastrous type is the indefinite low area which seems to divide in crossing the mountains from northern Georgia, the elevation of the land surface in the region appearing to assist the normal cyclonic functions in the production of heavy rains. Storms which first appear on the south Atlantic coast, coming from the ocean to enter the land, quite frequently lose their distinctive formation and resolve themselves into general rains of considerable duration, which cause floods when the area has drifted to the upper river basins. Tropical cyclones occur in August, September, and October at a time when the rivers are low, the conditions diminishing run-off at a maximum, and on account of their rapid movement are less to be feared, aside from the damage caused by wind and tide, than the more slowly moving depressions.

CONCLUSION.

The run-off of a river during floods is extremely variable, and the modifying conditions are very numerous and intricate in their effects, so that with our present knowledge the action of many of the factors above enumerated can not be estimated numerically. Figures given for the ratio of discharge to rainfall are of doubtful utility for river forecasting, although recent measurements of discharge are vastly more accurate than the older estimates. In the Ohio basin one-fourth of the rainfall is discharged; in the Missouri only one-seventh; in the St. Francis River nine-tenths.[a] The Cape Fear River during the floods of February or March certainly discharges as much as 90 per cent of the rainfall over its basin. To establish specific rules the forecaster must fix: (1) the gage relations of all stations on a river; (2) the rate of movement of the crest of the flood wave between stations; (3) the rainfall relation or stage which a given number of inches of rainfall in twenty-four, forty-eight, or seventy-two hours will cause at the verifying station. The publication of all the rules which have been established would be of great interest. Only a careful consideration of all the factors enumerated, a knowledge of the history of past floods, and some practical experience will enable the forecast official to make rules for forecasting in his district which will lead to success.

SHOULD THE TEMPERATURE BE VERIFIED BY MAXIMUM AND MINIMUM READINGS?

By Mr. P. F. LYONS, *St. Paul, Minn.*

[Read by title.]

The public in general considers that a day or a night is warmer or colder than a preceding day or night not by a comparison of the temperature at certain stated hours, but on the basis of whether it is warmer or colder at any time of the day or the night than it was at any time of the previous day or night, or, briefly, by the difference between the maximum or minimum temperatures for each successive day or night. However, the public is usually indifferent and will scarcely notice changes of 8° or more either way, except when the heat or cold goes above or below the limits of comfort, and then it will be impressed with changes of 2° or more, the impression being in proportion to the departure of the temperature above or below said limits. But aside from the public, science, it would seem, should require the most rational basis for determining the question and at the same time be in harmony with the public. In verifying temperature forecasts by the maximum and minimum I consider that science and public opinion will be completely in harmony.

But aside from harmony, the present method of verifying is often adverse to the forecaster. At night and during the cold seasons the difference is not much, but during the season when thunderstorms are common, I find in my experience, that it is considerable, for a warm day may succeed a much warmer or a much cooler one. The forecaster may forecast stationary or much higher temperature, according as the conditions on the map may warrant. The stationary or much higher temperature may follow just as he expected, but toward evening a thunderstorm may occur and cause a sudden fall of 8° to 16° in temperature, and just about the time for the evening observation (such occurrences are not so very rare) he would lose his forecast not only for stationary, but higher temperature, too; yet to the public the day was either as hot or much hotter than the preceding one.

The 24th of July, 1901, recorded as the hottest day at St. Paul, is offered as an instance. For that day the unprecedented maximum temperature was 104°, while at 8 p. m. it was only 85°. It was 96.5° at 8 p. m. of the preceding day, but the maximum was only 101°. The forecast for the 24th was "slight change in temperature." Immeediately after the registration of 104°, which was about 4.20 p. m., there came a thunderstorm and wind rush, which resulted in a fall of 30° by 6 p. m. After that there was a gradual rise, but not enough to justify the forecast, since colder weather would be the only forecast that could be justified under the circumstances, notwithstanding the public were forcibly convinced that it was the warmest day on record.

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[a] Physics and Hydraulics of the Mississippi River, 1861.

SECTION 4—RECORDS AND REPORTS.

ADDRESS BY THE CHAIRMAN, PROF. A. J. HENRY, WASHINGTON, D. C.

In the correspondence preliminary to the formation of a program several topics were suggested for discussion which, for one reason or another, had to be omitted from the final programme. With your permission I will reply briefly to some of them:

Binding of Forms No. 1009, Meteorological: I think Forms No. 1009 should be bound by all means. There will probably be a difference of opinion as to the best method of arranging them for permanent binding. The custom at the Central Office is to keep the forms together by months so long as they are frequently in use; for permanent binding, however, they are arranged chronologically by stations and bound by States. Generally three years' records are included in one volume.

Improvement of the original record (Form 1001) so as to adapt it for court use: Some official has suggested that the original record (Form 1001) could be improved with reference to its use in court. If the official had stated in what particular the original record is defective it would be much easier to discuss this question. The only defect I have found in it, so far as its use in court is concerned, is in the record of the time of beginning and ending of precipitation, on page 6. The record as now kept is not always understood by persons not connected with the service. It is therefore advisable to use the record of beginnings and endings found in the daily journal. In general, it is always preferable to furnish an account of the day's weather in the narrative rather than the statistical form. Too frequently the headings on meteorological forms fail to convey to the general public a true idea of the nature and character of the data given underneath.

A suggestion has also been made with reference to the improvement of the records in the interests of health seekers. I desire to call special attention to Form No. 1030, Monthly Meteorological Summary, as a means of conveying information regarding the local climate of a station. It contains, as you know, a record of the daily extremes of temperature, the daily rainfall, and the character of the weather, besides much statistical matter that is quite useful in studying local climate. It would be well to print an extra number of these forms and keep them on hand for supplying the information sought by health seekers and others.

We will now pass to the consideration of the papers on the program.

METEOROLOGICAL AND OTHER FORMS AND REPORTS: SHOULD THEY BE SIMPLIFIED; ARE MODIFICATIONS DESIRABLE?

By Mr. E. A. EVANS, *Richmond, Va.*

In a letter of March 19 last from the Central Office, relating to the contemplated work of this convention, the chief of Bureau was pleased to indicate his desire that a full discussion be had at this meeting of the methods now in vogue for conducting the business of the Bureau; at least so much of them as might properly come before this body. In pursuance of this it was later announced that the topic of "Meteorological and other forms and reports" would be discussed with respect to whether it was desirable and practicable to simplify or modify them.

The necessity for economy of time on stations is becoming a pressing matter with many of us, and more so now than ever, since the Bureau is growing and the demands upon us by the business and other interests of our respective communities are greatly increasing. Anything, therefore, that will tend to relieve the routine work of the stations so that time will be available in other directions would seem to be desirable.

The question, then, of the modification or simplifying of the forms in use, so far as it bears on this economizing of time, becomes a matter of some importance. I am free to say, however, that I do not see how any considerable saving of time is to be effected through modifications of our forms, unless a general revision and rearrangement of the system be had. As it now stands, it is the product of thirty years' practical working of the Bureau, and every form represents an existing necessity for it. From the standpoint of the man on station, however, there are some minor particulars in which it is thought changes for the better could be made. Let us consider for a moment Form 4013–Mis. (Monthly statement of maps issued). Does any essential need exist for the entry of the names and addresses, and dates on which taken up, of persons to whom maps are sent? Is it not practicable to omit these data? If it should be desired to know when a certain address was added or dropped from our list, could it not be more easily ascertained by referring to our complete station file of maps issued than through the medium of this form? Would not the essentials be supplied by giving in addition to the other data now provided for at the top of the form the total number of map addresses taken up or dropped each month? If this were done, the form could be reduced to the slip size, filing space saved—an important matter where thousands of them are filed, as at the Central Office—and the work of their preparation lessened in no slight degree.

The same is also true of Form 4028–Mis. (Changes in card forecasts). If it were allowable to omit entry of the names and addresses of persons or subcenters added or discontinued each month, the form could be reduced to the size of a brief fold and still make provision for all the important matter that caused it to be adopted in the first place, forming at the same time a ready means of ascertaining the amount of this class of work being done by each station. The name and address of each person receiving the forecast, both from the section center and all subcenters, together with date taken up and dropped, is doubtless kept on every station, and affords a convenient, accessible, and rapid means of getting at the particulars of any address, should such be needed for any purpose.

Again, in the case of Form 1022 (Hourly wind movement), why would it not be feasible to modify the instructions concerning it so that its tabulation could be done away with on long-record stations where a normal hourly wind movement has already been established? I do not know of any special use the data are being put to by the Bureau or the public, and it would seem as if for most scientific purposes the mass of this information already available would prove ample. Could not, therefore, a certain number of years' record be fixed upon as a standard, and then have all stations falling below it continue to compile the form until they have completed the allotted number of years? Would any important interest suffer if this were done?

Also in the case of the Daily Journal (Form 1014), would it not be practicable to omit unimportant dates? There are usually, as we all know, a number of such days each month, days on which there is absolutely nothing transpiring not fully shown by other forms, yet under the present rules an entry must be made on such days. Does not this tend to an undesirable duplication of data, and could not the rules be so relaxed as to allow such dates to be treated as the judgment of the observer may direct? It is not thought that the value of the journal as a whole would suffer on this account, as everything thus omitted could be found in the other forms. Further, as duplication is a matter to be avoided, why not also omit the times of beginning and ending and amounts of precipitation except where it comes from sleet or hail, or is excessive, or is possessed of some special or unusual features of interest. Ordinary cases of precipitation are fully provided for in Form 1001, where they are vastly more compact and accessible than in the journal. Moreover, the journal is designed to keep a record of such weather characteristics as are "not easily susceptible of tabulation," and precipitation is not only so susceptible but is tabulated right along.

A simplification or condensing of forms might also be accomplished in our semiannual property report by combining with it Form 2028 (Certificate of property expended), and providing a better or more commodious arrangement for accounting for Bureau property at the voluntary observers' stations. In the case of Form 2034, Property Report, this can be done, if not contrary to regulations, by adding a line on the bottom margin, which is ample for the purpose, headed "Y property expended," and another for "Disposition." Now, as all "Y" property is already carried on the regular return, the special advantage this arrangement would offer would lie in the fact that the complete record of property transactions would then be contained on the one form, thus facilitating comparison and checking and avoiding the liability to error arising from transferring data from one form to another. In so far as the apparent need for an improved method of accounting for property at voluntary observers' stations is concerned, while I am of opinion that it is desirable, I am not prepared to suggest a way of doing it. I have been using a specially ruled blank for this work for several years past which, while it answers very well, might be changed for the better.

With regard to our card forecasts, I think a change could be made that would result in a considerable saving of time and labor. It is doubtless the experience of all section directors that once the cards are introduced in a neighborhood, additional requests for them are constantly coming in. On star-route lines in particular, these applications entail much time and trouble in finding out what mail facilities exist before definite action can be taken. This, it is thought, could be remedied by printing upon the back of the forecast card the legend "Applicants for this card will please state the time their mail rider leaves the railroad station with mail." With this information contained in the application we could tell immediately whether or not he could be served, instead of, as at present, having to write the applicant one or more letters on the subject, or to call on our postmaster, or to hunt the information up in our mail contract books.

In considering the question of forms, as outlined by the letter quoted at the beginning of this paper, there remains but one thing more that it is desired to submit to this convention for discussion. It is as to the practicability of having all of the forms usually copied by letter press printed on thin paper similar to or the same as that used for the voluntary observer reports. The idea would be to put them up in the pad form and have the data entered thereon with indelible pencil, using carbon to obtain duplicates, the top copy to go to the central office and the duplicate to be filed at the station separately by means of some good filing device, forming books, as it were, that would hold a complete series of each individual form for a considerable number of years in a minimum of space and with a maximum of accessibility for reference, study, or other purpose. The effect of this would be to do away with the uncertainty and difficulty of obtaining good water copies, as is the case with forms made out with ink.

Now, Mr. Chairman, I believe it is generally conceded that the time of the man on station is valuable, and I am sure that if a feasible way can be found of lessening the work of preparing the forms in use he will heartily appreciate it, and that the time thus gained will be used to good advantage.

DISCUSSION.

Mr. E. C. Easton, of Baltimore, Md., spoke briefly of the advantage of using the card-catalogue system, which he stated was successfully used at Baltimore in connection with the reports of crop correspondents, voluntary observers, etc. He also described the method in use at Baltimore for filing blank forms, which consisted in taking the large envelopes used in mailing Form 1001 and placing each kind of form in a separate envelope, the grouped envelopes being stood on edge on shelves, whereby they are readily accessible. Mr. Easton submitted a schedule of work relating to meteorological forms for the information of the convention. The schedule follows:

DAILY.

Begin work daily at 12 noon, immediately after removing the wind sheet.

Count miles on wind sheet.

Enter miles on Form 1022. Verify totals for each six hours, for noon to noon, and for midnight to midnight.

Enter directions on Form 1021. Underscore 1 to 4 miles an hour. Where 0 miles are entered on Form 1022 enter 0 in corresponding space on Form 1021.

Verify entries of directions and velocities on Form 1001, 8 a. m. and 8 p. m.

Compute maximum velocities and directions and extreme velocity. Enter these figures on wind sheet in red ink and make permanent entries on Form 1001 in black ink. (It is customary here to make light pencil entries of maximum velocities until after the wind sheet is removed, when a more accurate measurement can be made.)

Compute precipitation. Enter beginnings and endings on wind sheet in red ink. Correct the register record to agree with the stick record. Enter amounts for each hour on wind sheet in red ink and make necessary entries on back of sheet. See that the twelve-hour amounts and other entries on wind sheet agree with the 8 a. m. and 8 p. m. entries on Form 1001. Make all totals and time entries on wind sheet agree with similar entries on page 6, Form 1001.

Compute sunshine. Enter "clear" and "cloudy" on wind sheet.

Compare entries on Form 1083 with entries on Form 1001. Verify the reductions of barometric pressure, dew point, relative humidity, and vapor pressure. Apply red ink correction figures to the trace sheet on the barograph for the two preceding observations.

Consider temperature entries for the preceding a. m. and p. m. observations, making a trip to the thermograph for the purpose. See that the maximum temperature is as high as, or higher than, the exposed temperature of the current and preceding observations. If, in the morning, the maximum temperature is recorded as being higher than the exposed temperature of the preceding observation, see that the thermograph trace confirms the entry. See that the minimum temperature is as low as, or lower than, the exposed temperature at the current and preceding observations. If, in the evening, the minimum temperature is recorded as being lower than the exposed temperature of the preceding observation, see that the thermograph trace confirms the entry. Make required red-ink entries on thermograph trace of differences for 8 a. m., 8 p. m., maximum, minimum, and special, temperature observations. Examine carefully the preceding twenty-four hour midnight to midnight period on the trace sheet for its highest and lowest temperature record, and enter the results (corrected) in proper columns on page 6, Form 1001.

See that cloud entries are correct, and that the total amounts and kind are consistent with the entry of "state of weather."

Special.—Enter dial reading on wind sheets on each Monday, and on first of each month.

Enter required reference to precipitation on the back of the last wind sheet for the month.

In correcting any part of the meteorological record at any time, always reflect whether the correction made involves other entries on the forms, and if so, carefully apply the resultant corrections in all places required. This is important, and should be done at once.

AT THE END OF THE MONTH—FORM 1001.

Obtain algebraic sums of "observed reading" and "total correction:" this should agree with sums of "station" in barometic columns. In like manner the algebraic sums of footings for "station" and "correction for elevation" should agree with sums of "reduced."

When computing mean current wind direction at 8 a. m. and 8 p. m., preserve record of work; the sums for each direction may then be used for entries of "number of times and percentage" in the summary, thus avoiding a repetition of work.

Always refer to special observations for pressure extremes, as indicated in note in Form 1001.

Page 6. See that the sum of "range" is the difference between the sum of "maximum" and the sum of "minimum."

See that "dep. since first of month" as given on last day is the difference between the sum of "mean" and the sum of "normal," and that it bears proper sign.

See that "dep. since Jan. 1," as given on last day is algebraic sum of "dep. since first of month" on last day of current month and "dep. since January 1" on last day of preceding month, and that it bears proper sign.

See that total precipitation is the sum of precipitation entries on pages 2 and 3.

Verify precipitation departures since first of month and since January 1, in manner indicated for temperature departures.

Review carefully all entries of beginnings and endings of precipitation. If rain was falling at a p. m. observation, see that dashes pass through the 8 p. m., "ending" space for that day, and the 8 a. m. "beginning" space for the following day, on page 6. If rain was falling at an 8 a. m. observation, see that dashes pass through the 8 a. m. "ending" space and the 8 p. m. "beginning" space for that day, on page 6.

THE EXAMINATION OF MONTHLY METEOROLOGICAL REPORTS OF VOLUNTARY OBSERVERS: IS IT DESIRABLE TO REPORT BACK TO THE VOLUNTARY OBSERVER THE ERRORS AND IRREGULARITIES DISCOVERED IN HIS REPORT?

By Mr. J. W. BAUER, *Columbia, S. C.*

It may appear at first glance that this question admits of a simple affirmative or negative answer. Nevertheless, there are underlying principles involved that merit careful consideration, and, although these principles are not confined strictly to this topic or to the work of the Weather Bureau, they fully cover it.

To take the negative side of this question might seem to be a purely selfish view of it, from the section director's standpoint only, and would be to give the increased work involved and the danger of unwittingly giving offense to a voluntary observer a greater prominence than to the principles that should govern us in our work.

The Weather Bureau is a part of the National Government, and as such the Bureau is strictly accountable to the public for the manner of performing the work in which it is engaged. Nevertheless, its work is not, strictly speaking, a governmental function. The work it does may gain a temporary weight or prestige because done under the fostering care of the Government; but eventually it is judged solely on its intrinsic merits. It might as properly be undertaken by private individuals or corporations, and no doubt would be were it not that the expense involved in collecting the necessary data and the difficulty of profitably marketing weather data, forecasts, etc., make it prohibitive.

The benefits to be derived from the forecasts and the other information furnished to the public are so many and so diversified, and are so intimately connected with the daily affairs of the whole people, as to make the work of the Weather Bureau a proper form of governmental paternalism.

In the light of the above, the topic may be discussed under three subdivisions, as follows: First, the relations to and duties owed the public by the employees of the Bureau; second, the relation of voluntary observers to the public; third, the relation of the Bureau to the voluntary observers.

For the purposes of this paper it will be sufficient to say, in discussing the first subdivision, that as paid servants of the people, selected to do a designated work and retained on account of their demonstrated skill and experience, the employees of the Bureau owe it to the public to render only such reports and publish only such data as have at least their own honest certificate of correctness, and which are as nearly accurate as their instruments, their knowledge, their skill, and their experience can make them. Anything short of this, "they eat the bread of their masters for naught."

The Weather Bureau compilations of meteorological records and data are accepted as conclusive evidence by the courts of law. This includes not only the observations taken at regular Weather Bureau stations, but also the records of voluntary observers, for the accuracy of which the Weather Bureau stands sponsor, and vouches for them under the seal of the Department of Agriculture. As individuals the employees often certify under oath to voluntary observers' records when such records are taken into court. These reports are at times taken upon the witness stand, either by securing copies from the voluntary observers or from the section center or from both places, and in the latter event it would discredit their accuracy if the two differed in any material respect.

No one has a just and meritorious claim on public gratitude for doing anything he is paid to do, except for the manner in which he does it; but when a man, or any number of men, take up a certain line of work that benefits their fellow-men more than themselves, they are deserving of the highest praise. In this class are the voluntary observers of the Weather Bureau. The record of observations taken at any one station covers but a limited area, and by itself would be of little account in determining the climatology of a region; yet when combined with the records of thousands of other stations, each one becomes an important factor in the whole vast scheme of climatology. The aggregation of voluntary observers' reports is possible only through the agency of the section centers of the Weather Bureau (or a like organization), and it is only when so collected or assembled that the highest value of even a single station's reports is developed. It is through this assembling that the public are enabled to have a share in the benefits derived or to be secured from voluntary observers' reports. However, when these reports reach the public, the latter have a right to demand as great an accuracy and reliability for them as though the reports originated in regular Weather Bureau stations. How can this result best be attained?

It is perhaps a universal experience—a truth that has been formulated in an axiom—that all men are liable to make mistakes. Who of us at sometime or other have not made mistakes and errors in his routine work as an observer, however conscientious in his efforts to avoid them? I venture to say not one. Is it reasonable then to expect absolute accuracy in the work of voluntary observers, when we, ourselves, can not avoid errors?

Admitting the desirability, as well as duty, of presenting the work of the Bureau to the public free of error, and admitting that errors are liable to occur, and frequently do occur, we come to the gist of the topic, which is, How can irregularities and errors best be corrected when discovered?

This brings into the discussion the mutual relations between the section directors representing the Weather Bureau and the voluntary observers. This relation may be, and often is, of a dual nature, namely, official and personal, perhaps better expressed as friendly or social. The two are not inconsistent. The first, although always pleasant, is usually formal, the latter sometimes very cordial. The section director regards the voluntary observer as an indispensable aid in his work, to whom all encouragement should be given and every courtesy extended, and who is worthy and deserving of all that can be done for him, either officially or in any other manner in which the director can show his appreciation. The voluntary observers are as a class, men who take up the work in a spirit of scientific investigation after truth, and in that spirit are as desirous as the Bureau possibly can be to have their observations and reports as nearly absolutely correct as painstaking care and thorough examination can make them. The first comes within the province of the observer himself; the latter is the duty of the section director. The voluntary observer is the best, in fact the only one competent, to decide what he intended to put on record in his Form 1009—Meteorological. The section director is oftimes the more competent to say how the matter should be recorded. Therefore, when an error or an irregularity is apparently discovered in any Form 1009—Meteorological, it would be presumptuous and show a lack of courtesy to correct the same without first communicating with the person who rendered the report. No voluntary observer should take offense upon receiving such a communication relating to the accuracy of his report, but, on the contrary, he should appreciate it as a kindness. In this, as in many other things, it is not so much the thing done as the manner of doing it that gives just cause for resentment. An error or an irregularity in a voluntary observer's report is neither a crime nor a misdemeanor, nor should the section director assume the rôle of censor, but when reporting back the discovery of an apparent error he should frankly and courteously inform the voluntary observer of the discovery, and ask that the matter be given careful attention, with a view of arriving at the truth.

The CHAIRMAN. The questions discussed by Mr. Bauer are vital ones. They must be met sooner or later by the section director. I commend them to your careful consideration.

THE BEST MEANS OF PRESERVING RECORDS FOR REFERENCE AND STUDY.

By Mr. S. C. EMERY, *Memphis, Tenn.*

The preservation of meteorological records and their arrangement in convenient form for reference and study are subjects of great and growing importance, and one well worthy of careful consideration.

The purpose of this paper is to offer a few suggestions regarding the compilation and arrangement of those data most often brought into use in connection with the ordinary business and professional affairs with which we are in daily contact, that in the end systematic and uniform methods may be adopted. Compared with present methods in this line, those.in vogue during the early years of this service appear extremely crude, and yet they were the best that the limited experience of the time could suggest. Later, as new features were added and the accumulation of data assumed greater proportions, old methods gave place to new, so that during the first eighteen or twenty years of the service changes in the manner of keeping the records were frequent, and not until about 1890 do we find the station record of observations in the convenient and satisfactory form now used.

The present record (Form No. 1001) is well suited for the purpose intended, and I can not see wherein it could be improved, being in compact and handy form for easy reference.

The recorded data for a single day is a relatively small matter, but, like bricks under the hand of the skilled artisan, the slowly added items soon form a monument in which the individual elements become obscured, and unless specially marked, many valuable ones are, for the time being at least, lost to sight. Therefore the necessity of setting apart the most commonly referred to elements in a convenient and comprehensive manner becomes at once apparent.

The successful merchant is the one who always aims to have on hand what the people want and when it is wanted. This can apply as well to the successful Weather Bureau official, who can have always at his fingers ends, if he will, anything in the way of weather lore likely to be required by the public he tries to serve. This may entail some extra labor and considerable patience, but in the end it will result in a great saving of time and vexation, and prove a source of satisfaction to the official as well as the inquirer.

The Weather Bureau station is a repository of interesting and valuable statistics in various forms, but unless these statistics and records are in convenient reach and so arranged that they can be found when wanted, they are of little use. Weather Bureau officials throughout the country are called upon daily, and often many times each day, for all sorts of information regarding past meteorological events and climatic data generally. This is especially true of newspaper men, who very frequently desire material for a weather story. In such cases, and in fact in most cases, comparative data are found most useful, for it is only through comparison that climatic statistics become intelligible.

I would first suggest the keeping of a sort of handbook, or station reference book, in which could be entered a roster of the station force and other employees, with a record of the various changes as they occur; all special instructions governing the conduct of the station, as well as those issued by the official in charge to the station force; addresses of all persons and places to which the various reports are sent, either by telegraph or mail; map and card lists, etc.; in fact, such a complete memorandum of the routine work that anyone suddenly assuming charge would have every detail before him. Then the daily maximum, minimum, and mean temperature, a separate page for each, and the daily precipitation, all arranged by months, and one page being capable of containing the data for a long period of years. By having the absolute maximum and the absolute minimum temperatures in red, or say all maximums above 90° and all minimums below zero, the particular temperatures most desired could be easily singled out. I have such a record and find it very useful. When once worked up from the numerous forms in which these data are usually found, its continuance from month to month is very simple and will well repay one for the trouble. When a sufficient number of stations have completed a period of thirty years or more, the data so prepared could be turned over to the Central Office for publication in book form.

In addition, the reference book should contain the monthly mean and normal monthly temperatures, daily normal temperature and rainfall, highest and lowest monthly temperature, and, if a river station, the highest and the lowest river stages during the month.

Another thing that would be found useful is an index to certain tables and reports in the Monthly Weather Review and other Bureau publications, so they can be readily referred to when necessary. This indexing can be done from time to time by simply making a note of reference to any article or table that the official might encounter that would seem likely to come into frequent use. I would also suggest the keeping of a brief record of all extraordinary occurrences, such as excessive rains, snows, protracted droughts, unusually hot or cold spells, severe storms, and floods, etc. Only a brief entry need be made, with a reference to the details elsewhere recorded. If given under proper heads and systematically arranged, such a record would be a great convenience and result in the saving of much time. It would also present a more or less complete history of the station, while a search through the old records, journals, etc., in the preparation of such history will familiarize one with past events as nothing else can.

The work herein mentioned could be accomplished by slow degrees, as time permitted, so that it would not be a great burden or interfere with other duties. It is probable that most stations have an arrangement of data similar or even better than that herein mentioned, but the object I have here in view is to secure complete uniformity in this regard and call attention to the need of a reference book suitable for recording those matters herein set forth, so that the same system may be in use at all stations.

Mr. J. D. Blagden, of the Memphis station, has proposed a very neat form of record, which shows at a glance the daily maximum, minimum, mean, and normal temperatures and rainfall in a way that is much more comprehensive than when given in figures, and also shows in a graphic manner the daily march of temperature through the seasons. Maximum wind velocities and snowfalls could also be treated in the same way, gales having their direction indicated. The record consists of vertical columns drawn to a scale on horizontally-lined paper, the distance between the lines representing a unit of the scale. For temperature the spaces represent degrees, and for precipitation and barometric pressure they represent one hundredth of an inch. By shading portions of the column and leaving other portions unshaded different data can be represented. This form of chart is frequently used in statistical work, and, being easy to prepare, I am of the opinion it can be used to advantage in meteorological work. However, instead of having each sheet contain the record for four months, Mr. Blagden proposes to have them one-half the size and contain the record for two months.

I would further suggest that a copy of the barograph and thermograph trace be kept at the station and attached to the corresponding data in the press-copy book of Form No. 1026 (where made), and that a press copy of the wind sheets be furnished all stations.

In conclusion, I wish to refer to a paper presented at the Omaha convention by Mr. Walz in regard to studies of climate, and to state that if some such plan as he therein outlines could be carried out at all stations, and every Weather Bureau station supplied with a copy, it would be a great convenience and fill a long-felt want. I would like to see such a plan carried out, and think with a little effort it could be, though possibly in a form somewhat abridged from that referred to.

The CHAIRMAN. The chair would state, in reference to the last part of Mr. Emery's paper, that an attempt was made several years ago to press copy wind sheets for all stations in order that a copy might be sent back to the stations. The labor of press copying was so great, however, that the attempt had to be abandoned. Press copies of the wind sheets for a few of the larger stations are now made, but it does not seem possible at present to undertake to furnish all stations with press copies.

With reference to the barograph and thermograph sheets, I would suggest that in all cases copies be made for file at the stations before forwarding the sheets to the central office.

THE NECESSITY FOR BINDING AND OTHERWISE PRESERVING THE PUBLICATIONS OF CLIMATE AND CROP SECTIONS.

By Mr. W. S. BELDEN, *Vicksburg, Miss.*

[Read by title.]

After the expenditure of much time, energy, and money in obtaining, tabulating, and printing reliable meteorological data the importance of properly preserving such publications becomes a question worthy of careful attention.

The two most important section publications are the weekly crop bulletins and the monthly section reports. Each publication has its special value, but to a very large extent the information contained in the former is to be found in the latter. Hence the necessity for carefully preserving the section reports at once becomes manifest. It is believed that at least two series of the weekly crop bulletins should be preserved and at the close of a season be bound with heavy manila wrapping paper by use of paper fasteners, labeled, and filed in a convenient place for reference.

The increasing number of voluntary observation stations and the gradual improvement in the character of the data which is compiled in the monthly section reports is commensurately increasing their value. Nearly all voluntary stations are now equipped with standard instruments and instrument shelters. Increased accuracy and uniformity in the time and manner of recording observations has resulted from the "Set Max." innovation, and improvement in the exposure of instruments is sure to follow the inspection of substations, for which provision has recently been made.

The monthly section summaries contain the detailed reports of the two most important meteorological elements, precipitation and temperature, observed at both the regular stations of the Bureau and all classes of substations using thermometers and rain gauges. In the preparation of these reports a great amount of energy and time is expended in order to accurately tabulate the results of all observations.

Within the past few years uniformity in size and in the general character and make up of the monthly section reports has been secured and a very handy file case provided in which to place a limited number of the loose reports as they are received from day to day. As these publications are beginning to accumulate and as their value is increasing from year to year, a uniform plan of preserving a portion of them by substantial binding should be given due consideration, along with other improvements to be made in the usefulness of the Bureau.

In order to lessen the cost of binding, and at the same time secure a volume not too large for convenient use, it is believed that the monthly reports of a section for a period of five years should be bound in one volume. Such a volume would be a trifle smaller than that of the monthly weather reviews for the year 1900, excepting in the case of Iowa and California, whose reports, being more extensive than those of other sections, should be bound perhaps biennially or triennially. As each section director finds greatest use for his own reports, and next to these the reports of neighboring sections and practically no use for the reports of many remote sections, the following plan of preserving the monthly section reports is suggested: The file case now in use being large enough to contain these reports for half a decade, let each section director at the end of five-year periods name about 10 sections whose reports are most frequently used and have these substantially bound, while those of the remaining sections may be preserved in fairly convenient form by binding with heavy wrapping paper, as was suggested for the weekly bulletins.

This plan would necessitate a cloth or board binding for about 500 volumes every five years, which can be well done by contract for $1 per volume and probably for a less sum.

While it would, perhaps, be desirable to have each section center supplied with the substantially bound monthly reports of all other sections, it is doubtful if this extension could be considered entirely practicable at this time.

THE USE OF COLLECTED DATA.

By Mr. W. S. Palmer, *Cheyenne, Wyo.*

[Read by title.]

Although I selected as a topic for this paper "The use of collected data," possibly I should have better indicated its contents had I headed it "The misuse of collected data," for that more clearly defines the topic I wish to discuss. I should never wish to discourage the true seeker after truth, the scientist, from the investigation of subjects and the reaching of definite conclusions from accurate and reliable data; but we are all aware that too many false conclusions are reached by investigators, not because the data used by them is not reliable and accurate, but because they have not fully considered all of the circumstances and conditions under which such data has been collected. In a recent number of the Monthly Weather Review the editor has very tersely stated this truth, as follows: "One may have the best of observational data and yet go far astray when he attempts to reason from it." If we are to reach true conclusions, we must be sure that data has been properly considered and that conclusions are logically correct, as our results must satisfy the criticism of the logician as well as the layman.

A great number of specific cases might be cited to illustrate this generalization already stated, but a few will suffice.

The possibility of an unwarranted conclusion is instanced in a recent issue of an agricultural journal. The writer states in broad and general terms that "southern Indiana, which has been cleared too much, years ago, when there was still much timber standing, produced far better crops than now," and that the destruction of the forests reduced the yield of crops. There is no reason to doubt the writer's ability to accumulate data showing that the forests of that section have been destroyed, and that there has been a reduced yield of crops, but the conclusion that forest destruction reduces yield of crops does not necessarily follow. If the essential elements of fertility are constantly taken from the soil, and none supplied, the soil will soon become exhausted, a fact strikingly illustrated by the many abandoned farms of the extreme eastern States. Could not the writer have ascribed the reduced yield of crops to the depletion of the soils, as well as to the destruction of the forests?

Much study has been given of late years to the subject of weather and crime. Most of the investigators, I believe, have confined themselves to data collected in the large cities of the country. If the records of the police department of a metropolitan city show that less of a certain kind of crime is recorded on exceptionally warm days than on other days, are we not as much at liberty to conclude that the police are less active on hot days than they are on days of a mild and pleasant temperature, as that less crime is committed? All factors which go to make up the data used should be considered and given due weight, if conclusions are to be accredited.

Some time ago a table of the frequency of hail in the United States was published in the Monthly Weather Review. The table referred to seems to show that the hail frequency in Colorado is six times as great as that of Wyoming, its near northern neighbor. During the period studied by the authors of the article there were about six times as many reporters in Colorado as in Wyoming, and six times as many hailstorms were reported for Colorado as for Wyoming. I believe that the fact of the number of reporters for the different States was not fully considered by the authors of the article, and the conclusions arrived at are not, at least to my mind, satisfactory.

I do not care to add other cases of a similar nature. As true investigators we should be careful, before arriving at our conclusions, that they follow logically from the data used.

RECORDS IN COURT.

By Mr. C. E. LINNEY, *Chicago, Ill.*

[Read by title.]

A record is defined as "a written memorial made by a public officer authorized by law to perform that function, and intended to serve as evidence of something written, said, or done." (See Railroad Company *v.* Morgan, 69 Ill., 492; also 115 Mass., 168.) What is evidence as here used? In its legal acceptation it includes all the means by which any alleged matter of fact, the truth of which is submitted to investigation, is established or disproved. (1 Greenleaf Ev., sec. 1.) If, therefore, a part of the means which it is desired to use to establish the truth of an alleged matter of fact be the official books, records, papers, or documents of an office of the executive department of the Government, the Congress has said that either the original or an authenticated copy is admissible to prove the facts therein contained. (Rev. Stat. U. S. (1878), sec. 882.) The wording of the statute is, "copies of any books, records, papers, or documents in any of the Executive Departments, authenticated under the seals of such Departments, respectively, shall be admitted in evidence equally with the original thereof."

It is not necessary that the book, record, paper, or document submitted should bear directly upon the point at issue; it is admissible if it tends to prove the issue, or constitute a link in the chain of proof, although, alone, it might not justify a verdict in accordance with it. (1 Greenleaf Ev., sec. 51; 134 Mass., 217; 54 Ill., 266; 5 Iowa, 535.)

Writings are of two classes, public—the acts of public functionaries in the executive, legislative, or judicial departments of the Government—and private, or those of the individual, which, in general, must be proved to be genuine. Public records, or writings, include those which the various officials of the Government are required to enter in books or registers in the course of their public duties, and which occur within the circle of their personal knowledge. Public writings are, further, judicial and not judicial, of record and not of record. There are also records which partake of both a public and a private character, for the former are wholly subject to public inspection, while the latter are not at all, thus a middle class arises which is called quasi public. These are not subject to the inspection of the public if the same is, in fact, against public interest. It is probable that the records, documents, papers, and books of the Weather Bureau may be placed within the latter class and, if in the judgment of the court, or of the chief executive officer, or the head of the Department in whose custody or under whose control these may be kept, the inspection would be injurious to public interests, an inspection will not be granted. (1 Greenleaf Ev., sec. 626; 109 Mass., 487.)

The general rule is that writings introduced in evidence must conform to the usual and ordinary tests of truth, the oath and cross-examination; but official registers or books kept by persons in public office in which they are required, either by statute or by the nature of their office, to write down particular transactions occurring in the course of their public duties and under their personal observation, and all other documents of a public nature are generally admissible in evidence, notwithstanding their authenticity is not confirmed by these usual tests of truth. An extraordinary degree of confidence is reposed in such documents and records because they have been made by an authorized and accredited agent appointed for the purpose, and also because of the publicity of the subject-matter. And since these records are made for the benefit of the public those who are given the authority to make the memorials really act as the agents of all the individuals who compose the State, and every member of the community may be supposed to be privy to the investigation. It follows, therefore, from the credit due to the acts of an agent, and from the public nature of the facts themselves, that such documents are entitled to an extraordinary degree of confidence, and it is not necessary that they be confirmed and sanctioned by the ordinary tests of truth. (1 Greenleaf Ev., sec. 483; 17 Ill. Ap., 136.)

These books, records, papers, and documents are recognized by law because they are required to be kept by law, because the entries in them are of public interest and notoriety, and because they are made under the sanction of an oath of office, or at least under that of official duty. (1 Greenleaf Ev., sec. 484.) It is deemed essential to the official character of these books and records that the entries in them be made promptly, or at least without such long delay as may impair their credibility, and that they be made by the person whose duty it was to make them, and in the manner required by law, if any has been prescribed. They belong to a particular custody, from which they are not usually taken but by special authority, granted only in cases where inspection of the book or record itself is necessary, for the purpose of identifying the book or record, or the handwriting, or, more particularly, of determining some question arising upon the original entry. When the books themselves are produced they are received in evidence without further attestation, but they must be accompanied by proof that they come from the proper custody, being presented by the official in charge of the station or some of his duly appointed assistants. (12 Price, 625; also 4 Price, 216.) Books of this public nature being themselves evidence, when produced, their contents may be proved by the introduction of an immediate copy duly verified. (1 Greenleaf Ev., sec. 484; 105 Ill., 419, and 27 Ill., 303.)

To entitle a book, record, or paper to be considered of an official character, or as an official register, it is not necessary that it be required to be kept by an express statute, nor that the nature of the office should render the book indispensable, it is sufficient that it is directed to be kept by the proper authority and that it is kept in accordance with that authority. (1 Greenleaf Ev., sec. 496; U. S. Stat. L. (L. & B's. Ed.) 133, sec. 1790.)

Where proof of a record is by copy, an examined copy, duly made and sworn to by any competent witness, is always admissible; but whether a copy certified by the official having the legal custody of the books, records, or papers, he not being specially appointed by law to furnish copies, is admissible, has been doubted, but Greenleaf says that the weight of authority is in favor of such copy being evidence, where the copy is given by a public official whose duty it is to keep the original. (See 1st Greenleaf Ev., sec. 485, citing 13 Fla., 602; 120 N. Y., 114, and 62 Me., 416; adverse 20 Ill., 144, and 105 Ill., 419.) This matter, however, has been anticipated, and in Instructions to Observers (1895), on page 23, we find this given:

> Officials of the Bureau must bear in mind that the records which they keep are a part of the records of the Department of Agriculture, and that by law they are in the custody of the Secretary of Agriculture. Officials in charge of stations will inform applicants that duly certified copies are always furnished when necessary for legal purposes.

And, as previously stated, these authenticated copies are made evidence by the United States Statutes. (Sec. 882, Rev. Stat. U. S.)

It is to be borne in mind, however, that these books, records, papers, and documents are in general not evidence of any facts which are not required to be recorded in them, and which did not occur in the presence of the registering officer. (1 Gilman, 347; 5 Mo., 403; 1st Greenleaf Ev., 493.) The general rule of law is that a certificate of a mere matter of fact not coupled with any matter of law is never allowed to be admitted as evidence. For, if the person making the record was bound to record the fact, then the proper evidence is a copy of the record, duly authenticated. As to matter, however, which he was not bound to record, his certificate, being without his official capacity extra-official, is merely the statement of a private person, and will be rejected. (17 Ill., 54; 6 Cowen, 261; 3 Peters, 12-29; 15 Mass., 336; 1st Greenleaf Ev., sec. 498.) Copies of records under the seal of the Secretary of Agriculture are deemed of a higher character and credit than sworn copies, because it is presumed that they have passed under a more critical examination. (1st Greenleaf Ev., sec. 503.)

The text in the decision of the City of Evanston *v.* Gunn (99 U. S., 660), which clearly sustains the records of the United States Weather Bureau, is as follows: Mr. Justice Strong delivered the opinion of the court:

> The admission in evidence of a record kept by a person employed by the United States Signal Service (United States Weather Bureau, authorized successor) at Chicago was objected to at the trial, not because it had not been properly made, identified, and proved, but for the alleged reason that "there was no law authorizing such records to be used, and because it was not competent testimony." * * * We have, then, only to consider the objections that were made, the only ones that appear in the bill of exceptions, and they present the question whether the record, conceding it to be properly proved, was competent evidence. It may be admitted there is no statute expressly authorizing the admission of such a record as proof of the facts stated in it, but many records are properly admitted without the aid of any statute. The inquiry to be made is, What is the character of the instrument? The record admitted in this case was not a private entry or memorandum. It had been kept by a person whose public duty it was to record truly the facts stated in it. Sections 221 and 222 of the Revised Statutes require meteorological observations to be taken at the military stations in the interior of the continent and at other points in the States and Territories, for giving notice of the approach and force of storms. The Secretary of War is also required to provide, in the system of observations and reports, in charge of the Chief Signal Officer of the Army, for such stations, reports, and signals as may be found necessary for the benefit of agricultural and commercial interests. Under these acts a system has been established and records are kept at the stations designated, of which Chicago is one. Extreme accuracy in all such observations and in recording them is demanded by the rules of the Signal Service, and it is indispensable in order that they may answer the purposes for which they are required. They are, as we have seen, of a public character, kept for public purposes, and so immediately before the eyes of the community that inaccuracies, if they should exist, could hardly escape exposure. They come, therefore, within the rule which admits in evidence "Official registers or records, kept by persons in public office, in which they are required, either by statute or by the nature of the office, to write down particular transactions occurring in the course of their public duties or under their personal observation." (Taylor Ev., sec. 1429; 1st Greenleaf Ev., sec. 483.) To entitle them to admission it is not necessary that a statute requires them to be kept. It is sufficient that they are kept in the discharge of a public duty. (1st Greenleaf Ev., sec. 496.) Nor need they be kept by a public officer himself, if the entries are made under his direction by a person authorized by him. (Galt *v.* Galloway, 4 Peters, 332.) It is hardly necessary to refer to judicial decisions illustrating the rule—they are numerous. A few might be mentioned, citing DeArmond *v.* Neasmith, 32 Mich., 231; Gurney *v.* Howe, 9 Gray, 404; Cliquots' Champagne, 3 Wall., 114; 70 U. S., 116. We think, therefore, that there was no error in admitting the records kept by the person employed for the purpose by the United States Signal Service.

RECORDS IN COURT.

By Mr. P. F. LYONS, *St. Paul, Minn.*

[Read by title.]

The meteorological records for St. Paul are frequently adduced, both in the State and the United States district courts, for the purpose, in most cases, of aiding to prove or disprove the claims of litigants in actions for damages to persons or property, and in which the weather may be a factor. In every case of importance, and on which wind, rain, snow, ice, fog, flood, and temperature may have a bearing, the records are either examined or brought into court as testimony by one or both litigants. Appearance in court, though often an inconvenience, ought not to be a hardship to an observer, since the court and attorneys are usually very obliging, and, when possible, will inform him by telephone or messenger just when they are ready to take his testimony. At times a certificate from the observer will be accepted in lieu of his presence. It is only when he is compelled to journey to outer places that there is much inconvenience; but even then there is no one of us, I presume, who is not ready and willing to undergo some inconvenience and even sacrifice in the furtherance of law and justice. But in doing so it is well to be prudent and cautious, and to be careful and not be led into the intricacies and mazes that may be laid by the skilled attorney and cross-questioner. It is unquestionable that the vast majority of attorneys are of high ideals, honorable, and upright; nevertheless, most of them consider, and no doubt rightly so, that it is not only their privilege but sacred right to astound or confuse a witness on the stand. A witness whose veracity may be doubted, or who may be suspected of bias, deserves to be so treated; but such treatment can not be said to apply to educated and disinterested public officials who base their evidence on official records, and severe cross-examinations, etc., can serve but little purpose aside from giving the attorney an opportunity to display his talent in that line. But if the witness confines himself to his records, and does not attempt to answer any of the theoretical or abstruse questions that may be put to him, he remains on impregnable ground.

In relation to the above, I will give two instances from my experience, in the first of which I appeared in answer to a subpœna last winter, in the district court of Ramsey County, State of Minnesota, in a case in which the city of St. Paul was defendant in a suit for personal injury alleged to be due to the city's negligence, and in which snow and ice figured.

When put on the stand, one of the attorneys for plaintiff commenced what I considered an effort to "work the jury" with a "Oh, ha; so you are Lyons, he—the man that guesses so much at the weather; prophet, eh?" The point that the city aimed to establish by my testimony was that the temperature rose above 32°, or freezing point, on the day of the alleged injury, and which it did establish. This was adverse to the other side, and so their attorney took me in hand, and, after parleying a little, suddenly put the question, "At what hour of the day does the temperature go above freezing, and when does ice or snow melt?" To which I answered: "The hour or time at which the temperature rises above 32°, or freezing point." He was evidently put out a little by this answer, and took another tack and parleyed some more, after which he suddenly renewed the question and quickly received the same answer as before. He then turned to the jury, and either in a real or feigned fit of irritation, exclaimed: "That's just like your people's method of prevarication." To which I replied, promptly and emphatically, "No other man can give you a more definite answer." That ended my testimony, and no further questions were asked, and I stepped down from the stand.

Shortly afterwards I was subpœned and appeared in the same court, and again in an action for personal injury in which the City Railroad Company was defendant. Their aim was to show that the snow on the ground was partly responsible for the alleged injury to plaintiff, who attributed it to the negligence of the railroad company. After testifying for the defendent, the attorney for the plaintiff started off with "Oh, so you are Lyons that we read so much about. Ah, well, Lyons, you consider yourself pretty reliable, don't you, and you are never off about the weather?" To which I replied: "That is for the public to decide. I don't consider it proper for one in the public service to indulge in self-praise," and that ended the matter, and I stepped down from the stand, as before.

The attorney in the first case mentioned, in my opinion, aimed to have me stultify myself by fixing an hour at which the temperature, when below 32°, rises above it, and in case of my attempting to do so he would not need to be a great attorney to compel me to show by my records that there was no fixed time for the temperature to rise above 32°, and that it might do so at any hour of the day or night. The attorney in the second casè, no doubt, desired me to extol myself by telling the court and jury how reliable I was, etc., and after that he would, no doubt, bring up some story about some forecast or other saying about the weather, and try to weaken my evidence or show that it wasn't worth much.

If the foregoing will be of any service to the officials of the Bureau in connection with the use of meteorological records in court, it will suffice for the little time spent in its preparation.

SECTION 5—CLIMATE AND CROP SERVICE.

ADDRESS BY THE CHAIRMAN, MR. JAMES BERRY, WASHINGTON, D. C.

From a meager beginning in 1887, when the National Climate and Crop Bulletin did not exceed in size any one of the 44 State Section bulletins now issued, the climate and crop service of the Weather Bureau has grown until to-day its several features constitute a work which, in the opinion of the speaker, is exceeded in importance and value by but one other branch of the Bureau's work, namely, the daily forecast and storm warning service, which, I think we all must admit, is the Bureau's first and most important duty.

With 42 well-organized State climatological services, besides those of Cuba and Porto Rico, we have a most efficient means for the collection and dissemination of information. We are amassing meteorological records from more than 3,000 stations, which, as well as providing for immediate use data required for current climate and crop publications, will prove of inestimable value to the future scientific investigator.

Until recent years the filling of requests from the various sources for special data constituted no small item of work at the central office in Washington. Now practically all such requests are satisfactorily met by the monthly reports of climate and crop sections. Scarcely a question can be asked concerning the climatic features of any part of the country, however exact as to time and place, that is not readily answered by these publications.

The national and the section climate and crop bulletins form a most complete history of the weather conditions throughout the period of planting, cultivating, and harvesting of crops. Much more might be said with regard to the system by which our crop work is conducted, but you are all familiar with it, and I will not consume time in dwelling thereupon.

In our climate and crop work we would be powerless to accomplish much that is valuable without the cooperation of our voluntary observers, displaymen, and crop correspondents, who give, without compensation, a part of their time each day, either in taking observations, distributing forecasts, or reporting the climate and crop conditions. Too much praise can not be accorded these public-spirited citizens for the sacrifices made to aid in this important work.

The foreign visitors, often the representatives of their respective governments, calling at the Weather Bureau, invariably evince a lively interest in the crop reporting system of the Bureau. They are favorably impressed with its thoroughness of conception and execution, and invariably express astonishment at the rapidity with which the work is accomplished, as well as admiration for its completeness.

The establishment of voluntary meteorological stations and the issue of climate and crop publications is not the only work conducted by the State climatological sections. It is through them that arrangements are made for the dissemination of the weather forecasts and special warnings. Nearly 2,000 forecast telegrams are sent out at Government expense daily to carefully selected points throughout the country, and these dispatches are multiplied by the various means of dissemination until a grand total of nearly 150,000 weather bulletins are displayed daily in time to give the public information as to the expected weather conditions of the succeeding day. In the dissemination of weather information the cooperation of the Post-Office Department, which is cheerfully given, is indispensable. From the Postmaster-General down to the rural free-delivery carrier our efforts in this direction are heartily seconded. Before the convention closes we will have with us Hon. A. W. Machen, the general superintendent of the free-delivery system of the Post-Office Department, who has taken a keen interest in forecast distribution through the rural free-delivery mail service of the Post-Office Department, and we have the best reasons for believing that his subordinates will assist, so far as they may without detriment to the postal service, in further extending this work. Two subjects in our official program relate directly to the work in which Mr. Machen is deeply interested, viz, "Is it advisable to distribute the night forecasts by the rural free delivery?" and "Weather symbols on rural free-delivery wagons," and before the close of the convention we will have the pleasure of hearing something of especial interest on these subjects directly from Mr. Machen.

With the rapid growth of the rural free-delivery service, and consequent increase in forecast distribution, the need for a forecast printing machine becomes more urgent. Professor Marvin has, I believe, so nearly perfected the Jermin device for card printing that I think the hope may be reasonably entertained that he will soon overcome the remaining obstacles.

While realizing the necessity for adhering closely to the official program, that it may be completed within the time allotted, I feel justified in referring briefly to a matter that may not be touched upon under any of the topics selected for discussion. I know that all our section directors are well informed as to the crops forming the principal staples of their respective sections, but I believe further attention to the subject is advisable, if not absolutely necessary, especially on the part of any who possibly may not yet have devoted that attention to the matter its importance demands. So far as I know, there does not exist any publication showing in graphic form, in sufficient detail, the areas devoted to the various crops. I believe that a part of the time of the section directors should be spent in the study of this matter, and, if necessary, data should be collected for the purpose of constructing maps showing the areas devoted to the several crops grown in their respective sections.

Not only should the areas devoted to the principal staples be accurately outlined, but those of many of the minor crops also. Suitable blank forms could be provided for the purpose of securing the needed data, which should be entered upon charts—a separate chart for each crop. These would also undoubtedly prove useful in studying the effects of the prevailing weather conditions upon the several crops. When the areas devoted to a particular crop are clearly marked out, any special information that may be desired respecting it at a critical stage in its development may be secured without calling upon the correspondents outside the area devoted to that staple. Take the tobacco crop in Maryland, for instance. Maryland does not rank high as a tobacco-producing State, yet there are some three or four counties in which tobacco has been the staple for generations; and if it were as extensively cultivated throughout the State as in these counties, the State would take high rank in the production of tobacco. In our work on the National Bulletin we find it of the utmost importance to have charted for each State on a map of the United States the percentage that State's product of any crop forms of the total product of all the States. This enables us to know what weight to give the statements respecting the condition of different crops as they come from the different sections. Take cotton for an example. Texas produces from 25 to 30 per cent of all that is grown in the United States, while some of the other States in the cotton belt make only about 5 per cent or less. We must exercise careful discrimination in weighting the several statements in the preparation of the general summary, the publication of which is now so eagerly awaited on Tuesday by those interested in crop production. And the section director should be very careful that his summary, which helps to guide the officials at the central office, should most correctly represent the conditions in his territory. It is to be hoped that the agricultural bulletins of the Twelfth Census will contain data in such detail as to afford our officials material that will prove adequate for such work without rendering the collection of additional data necessary. As soon as the agricultural bulletins of the Twelfth Census are issued effort will be made to have them supplied to all section centers.

One other matter before concluding. At every previous convention the importance of inspecting voluntary stations has formed one of the topics for discussion. I am glad to be able to say that initial steps looking to the general inspection of voluntary stations have recently been taken, and for the first time in the history of the Bureau section directors have been allotted small sums with which to defray personal expenses while making inspections. The sum allotted is not sufficient to enable each director to inspect all his stations, but with a moderate allowance annually the whole field will be covered in a few years, and then a most important work will have been accomplished. Thus, in this matter, as in many others of importance, we are gradually but surely accomplishing the desirable ends suggested and considered at our Weather Bureau conventions.

SHOULD THE MONTHLY REPORTS OF THE CLIMATE AND CROP SECTIONS CONTAIN ONLY ORIGINAL MATTER?

By Mr. G. A. LOVELAND, *Lincoln, Nebr.*

Whether the monthly reports of the climate and crop sections should contain only original matter depends somewhat upon the scope or purpose of the reports.

The tables furnish in a very compact and complete form the statistical data, and the charts graphically portray the distribution of the precipitation and temperature. The text supplements these by summarizing the conditions of the month for the section, both as regards meteorologically and agriculturally. These summaries are important and should not be too brief.

If the purpose of the publication is only to record a history of the weather month by month, then the plan is completed when the above is included. If, however, the object of the publication is to instruct as well as chronicle events, and to explain the unusual occurrences recorded whenever possible, its field is wonderfully broadened and it becomes a more ambitious monthly; perhaps, too ambitious for the time the section director is expected to spend on editorial work. Starting with the premise that some portion of the space occupied by text shall be reserved for an article containing information on some other subject than the month's weather or crops. There is no question but such an article would be better if original matter when possible, and it is about equally sure that the section director will not have sufficient time to prepare as many special studies as such a plan would require. Then he must resort to contributed articles or clippings. There is small prospect of receiving contributed articles from voluntary observers. The notes on the reports at the end of the month are about all that can be expected, and these, unless they record something very exceptional, are best used by the section director in preparing the summary. The voluntary observers are interested principally in the records of their own offices, and few of them have the data, if they have the time, to study general meteorology or even the climatology of the section. However, they would one and all thoroughly appreciate anything of this kind that might be printed in the monthly report.

The records amassed in each section afford ample material for investigation and study, and their compilation in such shape as to render them more available and valuable to the public is an important duty. This work can be done with peculiar effectiveness by the section director. No other person has like opportunities for obtaining information as to the climate and crops of the section. The people of the section will appreciate the results of an intelligent study of these records. Attractively presented in the monthly reports which will become an educating factor in the section and probably beyond its limits. If it is impossible to obtain worthy original matter, there seems to me to be no objection to reprinting an article or an abstract of an article on some pertinent subject. It seems that to have an article of a general nature, either of original matter or a clipping, will increase the value of the monthly report.

Mr. JENNINGS. The monthly climate and crop bulletin, I believe, can be made of considerably more value to the section in which it is published and which it represents if judicious selection be made of articles that can be utilized in that section. The Kansas Experiment Station issues a number of very practical bulletins. Last fall I quoted an extract from one of its bulletins regarding the soy bean. This spring in some of our southeastern counties the only crop that withstood the drought was the soy bean. The farmers had sent to the experiment station and obtained the seed, after having seen the notice in the monthly bulletin. There was a practical benefit. Some of the farmers might not have known anything about this soy bean if they had not seen this unoriginal article in the bulletin. We copied at one time, I think from the Arkansas section, an article that proved of general utility in the southern part of our State. The value of the bulletin can undoubtedly be enhanced by introducing judiciously selected matter from outside sources.

SHOULD THE REMARKS OF CLIMATE AND CROP CORRESPONDENTS BE PUBLISHED IN THE WEEKLY BULLETINS?

By MR. S. W. GLENN, *Huron, S. Dak.*

My views on this question are based on sixteen years' experience in climate and crop service work in Dakota Territory and the State of South Dakota. They should not be considered as criticisms of the bulletins of other sections. We all have the same object in view—to make our work of the greatest benefit to as great a number of general interests as possible. An exchange of views on this subject can do no harm and may result in much good.

I consider the weekly climate and crop bulletin the most important publication issued by the Bureau, and hold the view that it should meet, as far as practicable, the requirements of all interests that may be served by a knowledge of the condition and progress of crops from week to week. It seems to me that without some reference, both specific and general, to the remarks of correspondents, whether by literal publication of individual reports or by brief synoptic statements, the bulletin would hardly be what its title implies. If the publication were entitled "Climate and crop summary," a general statement of conditions and progress probably would be sufficient and might satisfactorily meet the demands of interests affected only by the total volume of crop production, such as boards of trade, cotton exchanges, chambers of commerce, railway companies, commission houses, and like extensive interests. These are generally well posted on the average production of the several crops grown in the different States and are accustomed to making estimates based on logical deductions and precedent lines of computation without regard to local limitations. Considered from the viewpoint of economy of time and labor, a matter of great importance to all section directors, the omission of the remarks of correspondents would doubtless be desirable.

However, for reasons later set forth, I believe such omission would affect adversely the present popularity and far-reaching benefits of the bulletins, especially of those issued west of the Mississippi River. Aside from the extensive interests mentioned, there are many others that are served by a knowledge of local conditions, such as wholesale establishments in all lines of trade, farm-machinery manufactories, lumber associations, produce dealers, trust and banking institutions having investments in farm securities, packing houses, the crop correspondents themselves, and, as regards our section of the country, the multitude that is constantly looking with hope toward the golden West. Experience has shown that very many of these have interests of local as well as general concern, and hence desire to follow the progress of crops from week to week, as affected by local conditions.

The division of the South Dakota bulletin into sections, a change from the former method of arranging the county reports alphabetically, regardless of location, was due to the increasing demand for local crop information. The character of the demands largely influenced the arrangement of the different sections, with special regard to topography, natural drainage, average precipitation, and adaptability of the soil to the production of the different crops. Not three months ago the Huron office received from one of the most extensive associations of its kind in the United States an application to be supplied weekly with 75 copies of the bulletin. The secretary later officially expressed the appreciation of the members, and spoke of the great value of the bulletins to them. Inquiries from other sources for local data have been frequent. Home seekers and men looking for business locations have informed me that their selection was largely determined by information received from the bulletin. Traveling agents of commercial houses are, for obvious reasons, frequently desirous of knowing the crop conditions prevailing in limited portions of the State.

Without the hearty, intelligent cooperation of crop correspondents the issue of the bulletin would be impossible. Many correspondents, who are farmers, not enjoying the convenience of rural free delivery, have at times to discommode themselves in order to mail their reports promptly, and I have good reason to believe that, in some instances, the desire to have their county represented has been the prime motive for their regularity. Furthermore, I am satisfied that the elimination of correspondents' remarks would tend to result, not only in irregularity of reports, but also in lack of interest on the part of correspondents, and hence a possible inadequacy of information. During the present season I adopted, for a time, the plan of omitting a county when the reports received were not sufficient to justify a concise statement of the conditions existing, especially when the conditions of the preceding week were of an uncertain nature, requiring full reports in order properly to set forth the changes of the current week. In nearly all instances such omission resulted in a very satisfactory quota of reports from the omitted county for the ensuing week. This, it seems to me, is positive evidence that the correspondents—the strongest factor in the crop bulletin work—desire to see their counties specifically referred to.

There is another reason, though remotely related to the existing general popularity of the bulletins, that should be considered. The individual interests affected by crop conditions, whether local or general, may be so great that a question as to the accuracy of the general summary will arise, and no better opportunity for prompt and ample verification of the general statement can be afforded than the reports by counties.

The conditions existing and the facilities afforded for collecting information may, and no doubt do, differ in the different States, and the different methods adopted for presenting the reports of correspondents are no doubt due to these considerations. In some States not only the literal remarks of the correspondent, but his name and post-office address, are printed, in some cases in rotation, because of limited space. This is a compliment which every correspondent richly deserves. However, it is in some cases impracticable, certainly so in South Dakota, where there are nearly 500 correspondents.

In the matter of securing and retaining correspondents the synoptic method of presenting county reports has been followed in South Dakota for a number of years with very gratifying success. I have yet to learn of any correspondent having been influenced to report from any motive other than the very laudable one of a general desire to assist in the work, aside from the personal one of having his county represented. For these reasons, as well as for general utility and accurate presentation of crop conditions existing from week to week, I am in favor of the synoptic method of publishing the reports of correspondents, the information being deduced from a careful and impartial consideration of all reports received.

If the demand exists for information of a more local character than can be fully met by a general summary, then the publication of the remarks of correspondents in some form is necessary. Assuming this to be the case, it would seem to be important that some uniform method of publication in this particular should be adopted.

DISCUSSION.

Mr. C. F. VON HERRMANN. Probably most section directors will concur in the views so well expressed by Mr. Glenn that the remarks of crop correspondents are a necessary adjunct to the bulletin. My own inclination is to file a dissenting opinion. While not quite favoring the total exclusion of remarks, I think they should not be made the chief feature of the bulletin. The object of the weekly crop bulletin is to present a general view of the condition and progress of crops as influenced by the meteorological elements over the limited area of a single State, eliminating minor irregularities resulting from differences in soils, methods of cultivation, original qualities of the seeds, etc. For this purpose a large number of correspondents is required as a basis for the preparation of a clear, comprehensive summary which shall truly represent the prevailing conditions. Now, North Carolina has 400 reporters, Texas 800. It is in most instances impossible to print the remarks from more than 40 to 70 places each week, and therefore the general practice is to adopt the method of rotation. Generally the remarks of any one correspondent may appear two or three times during a season. Considering the brevity and very general nature of the information furnished by correspondents it appears that this method fails to give details sufficiently definite to be of value for business purposes except in rare instances. To print the remarks from the same set of places regularly each week would discriminate against other points from which reports might be equally valuable to the public. The impression that it is necessary to print remarks to keep up interest in the work, in my opinion, is a mistaken one.

Most of our crop correspondents are practical farmers, and very properly so. The welfare of the farmer is so dependent on the influence of the weather that his so-called "personal equation" is very large. Bright skies and April showers place everything in a rosy light, while too much rain and weeds make every farmer, for the time being, a pessimist. In saying this I disclaim any intention to censure the work of crop correspondents, which indeed is indispensable and admirably suited for our purpose, but only to indicate that considerable experience and care in the preparation of a summary is necessary to avoid errors from this source. Readers of the bulletin may not possess the necessary discrimination. The crop bulletin should consist chiefly of a discussion of the effects of previous weather conditions which can only be properly treated by the expert in the summary.

The distribution of the crop bulletins is largely increased through the medium of the public press. The fifty or more newspapers in North Carolina that publish the bulletin do not repeat the remarks. Some newspapers in the larger cities may print the entire bulletin, but the country papers can not afford to do so. If chief attention is paid to the preparation of a satisfactory summary the reports of crop correspondents the summary will naturally receive more careful consideration. However, I think the form of bulletin generally adopted—a comprehensive summary followed by some selected remarks—is very suitable and I do not advocate a change. These simple considerations lead me to believe that the form of the Maryland and Delaware bulletin is the best.

The CHAIRMAN. The model bulletin, in my opinion, is one containing a comprehensive summary of weather and crop conditions, supplemented by data and remarks from as many correspondents as it may be possible to publish. I should consider the national bulletin not nearly so complete and valuable if the telegraphic summaries from State section centers were omitted, and they bear exactly the same relation to the national bulletin as the reports of the individual crop correspondents do to the local bulletin.

IS IT ADVISABLE TO DISTRIBUTE THE NIGHT FORECASTS BY THE RURAL FREE DELIVERY?

By Mr. M. E. BLYSTONE, *Springfield, Ill.*

In determining the desirability of distributing evening as compared with morning forecasts over rural free-delivery routes two principal things are to be considered: First, the comparative accuracy of these forecasts, and, second, the facilities offered by the rural free-delivery service for their distribution throughout farming communities. The first of these it is not my purpose to discuss at any length, as I have not at hand the percentage of verification of the two classes of forecasts, and I will only say that if the evening forecasts are as accurate as the morning forecasts they would seem to be the more valuable, in that they cover a period of forty-eight hours, while those of the morning cover a period of only thirty-six hours. But it will probably be urged that the more extended the period for which forecasts are made the less accurate they will be for the final portion of that period. This is undoubtedly true, and, since it is true, the forecast for the second twelve hours of the period will be more accurate than that for the third twelve hours. Whenever the time of mails is such as to permit it, carriers endeavor to start over their routes at a very early morning hour, and not infrequently the start is made as early as 6.30 o'clock.

If the carriers starting at this early hour can take the forecast with them, it can be made to reach the farmers over a large part of the route in time to enable them to plan the work of the day in accordance therewith, while if the carriers do not depart until 10 or 11 a. m. the farmers receive the forecast at such a late hour that its value for the day on which it is issued is greatly reduced. Such being the case, the forecast for the third twelve hours becomes the important one to the farmer, and the value of this must be compared with the second twelve hours of the evening forecast. The importance of having the forecast early in the day to which it relates is greater during the harvest season than at other times, but at all times farm work will be effected to a greater or less degree by a foreknowledge of probable conditions; but long before the morning forecast can reach him the farmer has planned the operations of the day and has them well under way.

The principal advantage in the distribution of evening forecasts is the completeness with which it can be made. Less than one-fourth of the post-offices in Illinois at which the rural free-delivery service has been established are able to take advantage of the opportunity to furnish the farming community with the forecast. With scarcely an exception the desire to aid in the work is expressed by postmasters, provided the forecast can be received early in the morning or at such time as to not delay the work of the post-office. In some instances the carriers start late enough to enable them to take the forecast, but the work of the post-office is such that the carriers can not undertake the distribution. I am led to believe, from the replies to my letters, that if the evening instead of the morning forecasts were sent out the limit of the territory covered by the forecast card would be nothing less than that of the rural free-delivery service itself. I have had some correspondence and conversation with officials of the Post-Office Department who are establishing and enlarging this service in Illinois, and I find that some of them are as enthusiastic for forecast distribution over rural free-delivery routes as are Weather Bureau officials themselves. I will not claim that the officials of the Post-Office Department are entirely disinterested in their enthusiasm. The rural free-delivery service is still in its infancy, and whatever may tend to popularize and strengthen it is rightly taken advantage of by those who believe in its value. Forecast distribution does this, and for that reason, as well as from the desire to promote the public welfare, all possible aid in this work is given to the Weather Bureau. It is hardly probable that sufficient importance is attached by post-office officials to the work to induce them to take it up at the expense of the postal service, nor can this be expected. The most serious objections offered by postmasters to delaying carriers until the morning forecast is received are found to be the necessity for the return of carriers in time to dispatch mail on outgoing trains and the bad condition of roads, which prevents them from making the return trip over their long routes at a reasonable hour. The former objection will always be effective at many post-offices, while ultimately, no doubt, the latter will be largely overcome by the improvement in roads, which it is hoped will attend the development of the rural free-delivery service. It will probably be a long time, however, before the improvement is very decided, and in States like Illinois, where much of the soil is of a nature that renders the construction of good roads a matter of enormous cost, this improvement will necessarily be slow. Another objection to delaying carriers that is frequently met is that farmers prefer to receive their morning papers early rather than to have the carriers wait until they can receive the forecast. The evening forecast is published in the morning papers, and with it there is frequently published a large amount of additional weather information in the way of synopses or tabular data, which appears to be as satisfactory to the farmers as the morning forecast would be. Indeed, the morning papers generally publish this information so completely and satisfactorily that, where they have a large circulation, I believe the forecast received in this way would serve the same purpose as if received by card, and take away the necessity for the latter method of distribution. In view of the fact that the weather forecasts are so highly appreciated, it would seem advisable to take the fullest possible advantage of this excellent opportunity to increase both the usefulness and the popularity of the service by using the evening forecasts. Wherever the morning forecast could be distributed at as early an hour as the evening forecast the former is, of course, of the greater value. At many places the time of arrival of mails is such that the carriers are compelled to start over their routes at a late hour, giving ample time for the morning forecast to be received and the cards stamped, and where such is the case it is desirable to continue to send out the morning forecast.

DISCUSSION.

Mr. SCHNEIDER. Michigan conditions are the basis for all my statements and conclusions, and these conditions, I suppose, are quite similar to those of most districts east of the Mississippi River.

On August 1, 1901, Michigan had 234 rural mail routes in operation, supplying on an average about 100 boxes each, or, roughly, about 23,400 families in all. Very soon after each route was established, the Lansing weather bureau office corresponded with the various postmasters for the purpose of enlisting their cooperation in rural forecast distribution, providing that the leaving time of the rural mail carrier was not earlier than the receipt of the a. m. forecast; if the leaving time was too early, a hope was expressed that the carrier could be held until about 10 a. m., at least during the planting, growing, and harvesting seasons. At present less than 100 routes are supplied with daily forecasts almost solely because the carriers leave their home offices before the time of receiving the a. m. forecast, which generally occurs between 9.30 and 10 a. m., central standard, or 90th meridian time; this standard is the time in use in Michigan. On some routes where it has been possible to distribute the a. m. forecasts the volume of regular business has gradually increased until it is a hardship for the carrier, an inconvenience to the postal authorities, and a delay of mail delivery to hold the carriers until about 10 a. m., and in a few cases the forecast distribution has been discontinued to enable the carrier to make an earlier start.

Along routes where there is no rural forecast distribution, the reason is almost invariably found in the comparative lateness of the receipt of the morning forecast, the postmasters deeming it impracticable to hold the carriers two hours after the rest of the business world has begun its work. In a very few cases postmasters have entirely refused their cooperation, but usually they express a strong desire to secure the rural forecast service, believing that their rural patrons will greatly appreciate it.

Still another condition which is worthy of note is the fact that the circulation of many Michigan and Chicago daily newspapers is so arranged that papers reach many of the rural mail termini early enough to be sent over the route; these papers all contain the p. m. forecast, and the question has often been asked by those interested why the Bureau does not use that forecast for rural route dissemination.

Present conditions (and probably future ones also) are: The a. m. forecast is issued too late for general rural dissemination. It is improbable that the leaving time of carriers will ever become generally as late as 10 a. m., a majority of them now leave considerably earlier.

In considering the advisability of using the p. m. forecast, it must be remembered that there is an almost settled policy in the Bureau that it shall not be used except for morning newspaper publication, and that its distribution is now largely accomplished through the medium of the press dispatches; it is also an administrative consideration that, except for the Washington a. m. and the two Pacific coast districts, the a. m. and the p. m. forecasts emanate from different offices; so that if the p. m. forecast were telegraphed out to a large number of post-offices for rural distribution it would entail much additional labor and expense to the Government. Nevertheless the discussion resolves itself into the question of whether, under the present conditions, the p. m. forecast shall or shall not be used and its solution will determine whether a large number of farmers shall or shall not be supplied with daily forecasts. I strongly favor a solution which will place the p. m. forecasts at the disposal of section directors for rural dissemination, because to the agriculturist, the coming weather is a matter of prime importance; he meets it face to face every day and all the day; there is not an operation in the field, garden, orchard, or pasture which is not modified, if not controlled, by the state of the weather.

The rural mail route has put an entirely new light on the matter of dissemination of forecasts and warnings in the country. It is a new condition, the importance of which is rapidly increasing, and it is necessary for the Weather Bureau to rise to the opportunity that now presents itself and give the agriculturist the benefit of its work.

In closing, a word may be added in answer to the possible objection regarding the confusion of the two forecasts which really appear before the public but a few hours apart. If the Bureau can give its p. m. forecast to the public through the morning newspaper, which reaches millions of readers, why should it not be used for the benefit of the farmer along the rural free-delivery mail routes until some new system is devised that will give the public only one stated forecast early each day, and which will serve both rural and urban interests alike.

The CHAIRMAN. We could reach thousands of homes in the rural districts with the night forecasts that can not be served with those prepared in the morning. Our chief difficulty in utilizing the rural free-delivery service in the dissemination of the morning forecast is due to the early departure of the carriers—before we can reach them with the telegrams. I am confident that the night forecasts would be gratefully received, and that they would prove valuable; but there are objections to using them for this purpose. As a rule, the telegraph offices in the smaller towns, from which the carriers depart, are not open until 8 a. m., so that the night forecast can not be made to reach the distributing point very much earlier than the morning forecast, which is based upon information received twelve hours later.

I would like to state that the hearty cooperation of the Post-Office Department in this work is consistent with its action in the past in other matters regarding the work of the Weather Bureau. A carrier in a Western State once refused to receive the forecast cards, and the matter was reported to Mr. Machen. He at once dictated a telegram to the postmaster directing that if the carrier persisted in refusing to receive and distribute the forecasts, he be suspended from duty. We had no further trouble.

HOW MANY CLIMATE AND CROP CORRESPONDENTS ARE REQUIRED TO MEET FULLY THE NEEDS OF THE BUREAU IN ITS CLIMATE AND CROP SERVICE?

By Mr. R. G. ALLEN, *Ithaca, N. Y.*

The number of climate and crop correspondents in each State should be sufficient at all times to insure receipt of reports from several well-selected points in each county. In New York it is found that the number of reports received during the planting, growing, and harvesting of crops is much less than at other times of the year, as the farmers, from whom correspondents are mostly selected, are too busy at that season to attend closely to the regular mailing of the cards. But it is at this time that many reports are required, as the uneven distribution of summer precipitation results in different crop conditions in adjacent sections. Local showers may greatly revive crops in some sections of a county while severe drought may continue for weeks in other sections of the same county. For this and other reasons, it appears to be necessary, in writing a bulletin which will reflect the true conditions, to receive reports each week from many parts of each county.

The number of reports each week should be just as many as the writer of the crop bulletin can digest; a larger number does not appear to be advisable, as the time consumed reading the additional cards could be given to better advantage to the preparation of the general summary. In order to receive weekly 250 to 300 cards, which are sufficient for the preparation of an accurate bulletin of a large State, it is necessary to have a list of 500 to 600 correspondents.

DISCUSSION.

Mr. HACKETT. The more reports we receive, provided we can read and thoroughly digest them, the more accurate will be our summaries, and it seems to me that the controlling factor in selecting crop correspondents should be to get as many reports as we can advantageously use in preparing the bulletin and summary. In Missouri there are about 500 correspondents, representing 114 counties, and we receive from 250 to 400 reports weekly. If a special request is sent out, nearly all correspondents reply, and their reports I find ample for all needs. In important agricultural States I think there should be three or more correspondents for every county. It would probably be an advantage in some counties, where there is a great diversity of crops, or where special attention is given to some particular crop—fruit, for instance—to secure one or two observers in that county to report on that crop and nothing else. I find that a very good plan, as it gives me the advantage of the judgment of people who are in a position to know more about a particular crop and are better able to judge of its progress, the injurious effects and conditions, than those who are not making a special study of it.

The CHAIRMAN. I do not think anyone can handle three or four hundred reports and accurately sum up the situation regarding each crop from memory. It is absolutely necessary to jot down the facts on charts, one for each crop, and after all the information has been charted the section director can discuss intelligently the condition of each crop. I think that is the plan of all our section directors. If it is not, I will say that the Central Office will be glad to provide a base map of each State on a sufficiently large scale to enable the section director to plot thereon the conditions indicated by the reports.

As to the necessary number of climate and crop correspondents, I know there is great diversity of opinion. I think the total number of our crop correspondents could be increased with advantage. Our lists for all States aggregate about 14,000. I am disposed to think that this number should be increased 25 per cent, and, furthermore, that there should be a reserve list amounting to 25 or 30 per cent of the active list, to be called upon as occasion may require. The distribution of the correspondents is a matter of much importance.

Mr. CHURCH. I had some acquaintance with crop correspondents before I went into the Department of Agriculture. It occurs to me that there is one factor that might be considered. The number and value of the reports of crop correspondents seems to me to be very largely governed by their geographic distribution. In the large farming counties in the West, if the section director can so distribute his correspondents that every part of the county will be represented, I think the worth of their work will be largely enhanced. It is better to have a county divided into three districts and a responsible and intelligent correspondent in each one of these districts, making three, than to have three correspondents from one school district, for instance.

PHENOLOGICAL DATA.

By Mr. J. WARREN SMITH, *Columbus, Ohio.*

To show that there is need for such data and the value and importance of keeping notes on the dates of planting, growth of crops, and harvesting, I wish to quote from a recent letter from Prof. Chas. E. Thorne, director of the agricultural experiment station, Wooster, Ohio:

> Experimental sowings of wheat were made last fall by this station at Wooster and Strongsville, 40 miles north, on dates a week apart, through September and into October. The present condition of the wheat shows a destructive attack of hessian fly, occurring between September 8 and 25 at Strongsville and between the 7th and 28th at Wooster, the severest injury occurring to wheat sown between the 15th and 22d. Wheat sown September 28 to October 5 at both places now promises an abundant yield, as does wheat sown on October 4 and 5 on the State University farm at Columbus, where no earlier sowings were made. I am informed, however, that wheat sown October 8 to 10 in Gallia County was severely injured.
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> I find, on referring to the report of the Michigan board of agriculture for 1877, that Prof. A. J. Cook, then of the Michigan Agricultural College, gave September 20 as the date of probable earliest safety in his latitude, deducing this date from a consensus of observations running back half a century and made chiefly by Fitch, of New York, and himself, but he called attention to exceptions to this date noted during the attack of the fly in Michigan, which had extended from 1875 to 1877, exceptions in which the date named seemed not to have been sufficiently late to avoid injurious attacks; and Dr. James Fletches, Dominion entomologist of Canada, has recently recommended that sowing be delayed in Ontario until the last week of September. It thus appears that the date of safety may be between three and four weeks later for the latitude of southern Ohio than for that of Ontario and Michigan, 4 degrees farther north, but that this date is liable to vary in different seasons.
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> What seems to be needed is some natural phenomenon that will mark the transition from summer to autumn and by which the farmer may be guided in his seeding. Frost is such a phenomenon, and frost may possibly have the further

useful effect of destroying the eggs or young larvæ of the fly. I fail to find records of observations on this point. But last year the frost failed to come, and all over Ohio the corn crop matured and went into shock unfrosted, something I have never observed before, although it may have occurred.

There is an old farmers' rule that corn should be planted when the white oak leaves are as large as a squirrel's ear. This gives a date which moves backward or forward with the earliness or lateness of the season, and also gives a phenomenon by which we may mark the progress of the season from south to north. Could we have observations on this point and on some similar phenomenon in the fall, such as the first coloring of the sugar-maple leaves, care being taken in this case to mark the general appearance of the autumn coloring and not some isolated instance which might be due to accidental causes, we might trace the backward progress of the summer across the State.

Such observations as these, extended through a series of years, would give information of great practical value.

We also need, and that at once, reports from careful observers respecting the condition of wheat sown at different dates last fall, for, much as has been written about the date of sowing to avoid the attack of the fly, it is evident that we as yet know but little about the matter.

This letter not only shows the need for such data, but indicates the appreciation of the writer of the valuable and complete system that the Bureau has in operation in connection with its observers and correspondents.

I published this letter in full in our monthly report for April, and to date have received phenological data from just one observer.

I believe that others have such memoranda, and it should be one of the duties of the section directors, in inspecting voluntary stations, to ascertain whether the observer or some other person in the neighborhood has not been keeping them.

To secure such information is, to my mind, one of the advantages of inspection, and I believe that the director should remain long enough in a neighborhood to secure information about the crops, the neighborhood, the topography of the district, and such weather and climatological data as may be available. Then, at his first opportunity, he should correlate the conditions and results. Mistakes may be made and incorrect conclusions drawn, but in time valuable data will be accumulated.

To encourage observers and correspondents to record phenological data a suitable form should be prepared and sent out to them each year. It may not be desirable to have this form cover more than two or three of the principal crops of the neighborhood, together with the leafing and flowering of certain trees, as suggested by Professor Thorne.

For example: The data for corn should show the date of planting, of appearance above the ground, of one intermediate stage of its growth, of tasseling, shooting, and ripening. Space should be given to record the attendant weather, and for noting any well-defined reason for unusually early or late dates.

All observers would not have the time for this work, but I am sure that a sufficient number in each State could easily be secured to make the results very valuable.

DISCUSSION.

The CHAIRMAN. I consider this a very interesting subject. So far as I know phenological records are very scarce and fragmentary. A few years ago an effort to gather some information along this line was made, but it was not rewarded as fully as we anticipated. I was much surprised to learn that the agricultural experiment stations at that time were not able to materially help us. I fully agree with Mr. Smith that some blank form or diary should be provided, and its use encouraged among our voluntary observers and crop correspondents. As to the character of the form to be used, I am not fully satisfied that we have yet devoted sufficient attention to the matter to enable us to determine just what may be best, but by inviting suggestions we can prepare a form that will doubtless meet the requirements.

CLIMATOLOGICAL STUDIES WITH REFERENCE TO THE CROPS OF THE SEVERAL SECTIONS.

By Mr. C. F. von Herrmann. *Raleigh, N. C.*

The study of climate in relation to agriculture involves chiefly an investigation of the influence of the meteorological elements upon the structure and growth of plants. This problem is an extremely complex one. It is difficult, indeed often impossible, to distinguish sharply between the effects of climate and those modifications which are brought about by the varying physical and chemical nature of the soil, the action of the lower forms of life, or the work of man. The object of the agriculturist is to improve the quality and the yield of crops by suitable application of fertilizers, proper modes of culture, and by constant selection of the best seeds and the introduction of new and improved varieties. The favorable or adverse influence of the weather, however, so often completely controls the results of the farmer's efforts that no subject in the whole domain of agriculture is of greater importance than the study of climate and crops. The aim of this paper is not to discuss the intricate relation of climate to vegetation in general, but rather to point out the methods which may be most suitably employed by the Bureau in practical investigations of crop conditions and yields, and the direction in which voluntary observers may be persuaded to extend their work.

Plants reflect the influence of the meteorological elements in two ways. In the first place they possess a fixed, inherited habit of development, which is largely the result of the normal climate of the region to which they are indigenous or in which they have become acclimated. The influence of permanent climate only, not the changeable conditions of a season, has produced during past ages those variations in plant structure which, by natural selection, have developed the innumerable species now existing. On the other hand, every plant is immediately modified during a single season of growth by varying weather conditions, an excess or deficiency of moisture, frost, or heat, which interferes with the efforts of the plant to complete its growth and mature its seeds in the normal way. From this point of view there are two lines of investigation open to us: the one includes the microscopic examination of plant structure and the distribution of vegetation over the globe which depend on climate, and the other the study of economic crops as affected by the weather from day to day.

Climate has produced many special adaptations in the minute structure of plants, such as the wonderful provisions for regulating the loss of water by transpiration, or of lessening the influence of intense insolation, which are used by the botanists as the criterion for the classification of plants on a physiological basis, and are important in the study of the geographical distribution of vegetation. As this is preeminently an age of specialists, the study of plant anatomy and plant geography must be left to the botanist, since these subjects require a more extended knowledge of botany than members of the Weather Bureau may reasonably be expected to possess. Indeed, plant structure and the relationship of the zones of vegetation to climate have been relatively well studied, and the literature of the subject, especially in the German language, is very full. The most satisfactory treatment of this subject and the finest collection of illustrations ever published will be found in the recent elegant and authoritative work by A. F. W. Schimper.

By the term "weather" is understood the phenomena presented at a definite time by all the meteorological elements acting together. Our efforts are directed toward establishing some definite correlation between the growth and yield of crops and the vicissitudes of weather which they undergo from day to day. We know that growth depends upon temperature; for each species there is a maximum and a minimum degree, beyond which the plant perishes, and an optimum, which secures the most vigorous growth; light causes assimilation and enables the chlorophyl to decompose the carbon dioxid of the air; water acts as the medium by which food is taken from the soil; a plant secures its best development when each factor reaches a maximum of favorable influence at the proper moment of time. The most practical work of the climate and crop sections will be directed toward extending our knowledge of these phenomena. In fact, the weekly crop bulletins published by every section and by the national service, which have become so important a feature of our work, are the results of efforts in this line.

The study of climate in relation to the crops of the several sections may be conducted by examining, in comparison with prevailing climate, the statistical material in regard to crop conditions, and by cooperating with or adopting the methods of the agricultural experiment stations in the investigation of special crops.

1. The information furnished by crop correspondents which is utilized in the preparation of the weekly bulletins is too general and vague for strictly scientific purposes, however valuable it may be for immediate business interests. Information of greater detail by more skillful observers is required. The statistical branch of the Department of Agriculture publishes during the growing season monthly statements of the condition of every important crop for each State in percentages. The percentage statement for a crop in the limited area of a single State represents largely the result of previous weather conditions in as exact a form as can at present be attained. By taking the percentage condition of a crop for each month for a series of years and studying the figures in connection with the temperature, precipitation and sunshine records, and the departures from the normal at all regular and voluntary stations, certainly some definite laws of value to agriculture will be obtained. This is a more detailed and extended method than the mere comparison of crop yields with the climatic conditions for a year.

2. The sections certainly should cooperate with the agricultural experiment stations and adopt the method of studying the cultivation of plants upon special plats. For this purpose it is not necessary that section directors engage directly in raising crops, but only that information be sought from those who are practically and successfully growing the crops under investigation. Taking up a special crop, it will be easy with our present printing appliances to prepare a schedule of questions covering every phase in the growth and development of that crop, its useful variations under different climatic conditions, etc., to be sent to as large a number of well-known growers as possible. The answers should be studied in the light of knowledge and experience gained from every available source. Some years ago

the Weather Bureau employed several scientific men on the staffs of the experiment stations to make special reports on single crops, and I recall particularly an excellent bulletin on the Climatology of the Cotton Plant, by Prof. P. H. Mell, of Alabama, which will indicate what might be accomplished in this way. The method here outlined would require that section directors select special subjects in connection with crops for investigation.

For scientific studies more than the elements of temperature and precipitation are required, but at present it does not seem advisable to increase the instrumental equipment of voluntary observers. They may be persuaded, however, to extend their work by undertaking the study of wild and cultivated plants in relation with the records of temperature, precipitation, frost, etc., or phenology. A detailed record for a selected list of plants, of the time of sprouting, leafing, and flowering, of the ripening of the fruit, time and yield of the harvest, would help to lessen our ignorance of the laws of plant life.

In conclusion, mention may be made of a few of the innumerable problems that suggest themselves for solution. We must ascertain the proper climatic conditions that will assure the largest and best yield of every crop and be able to predict the time and character of the harvest; whether plants can be successfully grown in localities where it is desirable to introduce them; what variations climate produces in the specific qualities which render plants useful, for instance, in the saccharinity of sorghum or of beets; in what section shall we be able to develop flax with sufficient pliability of fiber, or tobacco with the most desirable color and flavor. The protection of fruits in orchards or in transit is part of the problem. Finally, considering the innumerable species of plants in existence, there is the possibility of largely ncreasing the number of those which are economically useful to man.

MARYLAND CLIMATOLOGICAL STUDIES.

By Mr. O. L. Fassig, Ph. D., *Baltimore, Md.*

The Maryland State Weather Service was organized in 1891 by the present director, Prof. William B. Clark, of the Johns Hopkins University. It is conducted under the joint auspices of the Johns Hopkins University, the United States Weather Bureau, and the Maryland Agricultural College. In 1896 the Maryland and Delaware section of the climate and crop service of the United States Weather Bureau was established, with headquarters at Baltimore. The director of the State service, being thus relieved of the labor and expense of collecting and publishing weather and crop data, outlined a new plan of work, which is now being carried on with the cooperation of the national Bureau, under the direction of Prof. Willis L. Moore.

The director of the State service is also State geologist. The provisions of the legislative acts establishing these services are broad in their scope, while the appropriations are ample under the circumstances. Taken together they afford an opportunity for a thorough survey of the physical characteristics and the natural resources of the State.

It is the purpose of the State service to devote its energies in the future chiefly to the publication of special reports on the climatology of the State, giving to the term climatology a very broad interpretation. Special volumes will be prepared on agricultural and medical climatology and the more closely related phases of physiography, hydrography, forestry, and soil conditions.

The results already accomplished have been made possible, with the moderate State appropriation available, by the broad-minded policy of cooperation between State and nation when working along similar lines. The director has on various occasions publicly expressed his indebtedness to the Secretary of Agriculture and the Chief of the Weather Bureau for their great personal interest in the work done in Maryland. The first fruits of this cooperation are embodied in Volume I of the new series of the Maryland State Weather Service Reports. The volume is doubtless familiar to you all. The extent of the cooperation between State and national bureaus may be judged by the fact that three of the four contributions which go to make up the volume were prepared by members of the Weather Bureau. The volume was planned and published by the director of the State service, while by far the larger portion of it was written under the direction of the Chief of the United States Weather Bureau.

The volume is devoted to a description of the physiographic features of Maryland, by Dr. Cleveland Abbe, jr.; to a general presentation of the aims and methods of meteorological work, by Prof. Cleveland Abbe, sr.; to an historical sketch of the progress of meteorological work in Maryland, by the speaker, and to an outline of our present knowledge of the meteorology and climatology of Maryland, in which Mr. F. J. Walz has presented an elaborate reduction and discussion of Maryland climatic data available at the time.

Other volumes of the same general character are to follow. Volume II, as at present outlined, will be devoted to the reduction and discussion of the Baltimore observations of the United States Weather Bureau from the date of the establishment of the station, in 1871, to the close of the year 1900, a period of thirty years. Considerable work has already been done by the speaker upon this memoir on the climate of Baltimore. Much time and labor will be required to complete it. An attempt will be made to present, in attractive form, the results of the long series of accurate observations made at great expense by the National Government. The volume will contain, probably in addition, a memoir upon the average distribution of atmospheric pressure over the globe and its influence upon the weather of the Middle Atlantic States.

The State geologist has begun the publication of a series of county reports upon the geology and physical features of Maryland. A separate volume is to be devoted to each of the twenty-three counties of the State. Each volume of this series is to contain a chapter upon the climate of the county under consideration. The volume on Allegany County appeared some months ago. The climatological data for Garrett County, in the extreme western part of the State, and for Cecil County, in the extreme northeastern portion, are now being reduced and discussed for early publication. These county climatological studies, should the series be completed, will probably be reprinted and gathered into a future volume of the Maryland State Weather Service Reports.

State weather services have now been in existence for periods ranging from eight or ten years to twenty and more years. In many States the period of observation at one or more stations extends much farther back, affording excellent material for contributions to the study of local climates. The time is now ripe for collecting and intelligently discussing this vast fund of valuable observational material and placing the results within reach of the people. This is what is being done in Maryland. We are fortunate in being able to publish results in an attractive form, the graphic arts figuring largely in the composition of the reports. Being addressed primarily to the general public, they are mostly free from purely technical forms of expression or manner of treatment.

Valuable work can be done along these lines at many section centers, even without a special fund for publication. The preliminary work of collecting and discussing the data requires time, but there is little or no additional expense connected with it. While but little space is available in the columns of our monthly climate and crop reports for the publication of local climatological studies, still many valuable contributions of an original character may be made possible in this manner by a judicious use of the few columns not filled with tabular matter or charts.

DISCUSSION.

F. J. Walz (Chicago, Ill.). A comprehensive study of the climatology of Maryland was undertaken by the writer in 1898-99, and the results published under the auspices of the Johns Hopkins Press in Vol. I of Maryland State Weather Service Reports, 1899.

As Dr. Fassig has given a complete outline of the work attempted at that time, as well as that contemplated along this line for the immediate future in the State of Maryland, I shall pass over that portion of the discussion and only attempt briefly an explanation of what was considered accomplished in those studies in the attainment of climatic knowledge of the State of Maryland.

The object of the studies and their publication was to set forth in a brief and concise way the climatic conditions of the State in its various physiographical divisions, and to give the information in such form as might prove attractive, and at the same time suitable to the needs of all desiring information regarding the climate and weather of Maryland. General facts were presented, as far as possible, and the results and deductions from the observations of weather elements were given, rather than a vast amount of tabulated records, tables being introduced only where it was deemed necessary to give in full such data as might be practically useful.

A little in the way of showing causation for the variations in climatic conditions was also attempted. The study was prepared under the following heads:

General Discussion.—Under this head were presented briefly the more important of the general laws involved in producing the climate of a place. The operation of the four main causes of the varied character of climate, namely, latitude, elevation, distance, and location with reference to the sea and prevailing winds.

Meteorology, or Weather.—Under this head were discussed the distribution, character, and movement of pressure areas.

Climate.—Under this head were described:

(1) The geographical location and physiographic features of the State, an intimate knowledge of which is necessary to the discussion and understanding of the climate of any section.

(2) The condition of the atmosphere in regard to heat and moisture for every portion and physiographic section of the State; that is, the normal temperature and rainfall, with the departures therefrom, and distribution geographically and chronologically.

METHODS OF SAVING TIME IN THE DISTRIBUTION OF FORECASTS.

By Mr. W. T. BLYTHE, *Indianapolis, Ind.*

The methods of saving time in the distribution of forecasts vary with the conditions existing at the several distributing stations, the kind of forecasts, the telegraphic, telephonic and mail facilities, and messenger service available.

For convenience in this discussion, and for the information of those who are not members of the Weather Bureau, it is deemed advisable to describe briefly the different kinds of forecasts issued and the several classes of stations. Daily forecasts are of two kinds, viz, State and local. State forecasts are those prepared to cover the general weather and temperature conditions in the State, as a whole, during the period named therein—not less than twenty-four hours, usually thirty-six, frequently forty-eight, and sometimes a period of greater length. Local forecasts differ from those made for the State only in that they are confined to the locality of the station at which or for which they are made.

Distributing stations may be classified as follows: Forecast district centers, forecast distributing centers, forecast display stations.

The United States is divided into seven forecast districts, the headquarters or central offices of which, named alphabetically, are: Boston, Mass.; Chicago, Ill.; Denver, Colo.; New Orleans, La.; Portland, Oreg.; San Francisco, Cal., and Washington, D. C. To each forecast district center is assigned a certain territory, embracing several States, and it is the duty of the official in charge or some other qualified member of the office force, designated by proper authority, to make daily forecasts for each State in his district. Copies of these State forecasts are sent by telegraph and telephone to all regular Weather Bureau stations in the States for which they are made, to such forecast display stations as can be reached with least delay direct from the district center, and to certain forecast distributing centers (to be described hereinafter); are furnished press associations and daily newspapers; by telephone to commercial exchanges and public institutions to be bulletined upon blackboards; printed upon the weather chart and, by the logotype process, on postal cards, for general distribution by messenger or mail for the benefit of the public.

Forecast distributing centers are stations designated as such by the Chief of Bureau because of their locality and superior telegraphic facilities. The service required at such stations is precisely the same as that at district centers, with this one exception, that the forecasts are not sent from them to other regular Weather Bureau stations. Forecast display stations are selected places where the postmaster, or some other public-spirited person, gratuitously cooperates with the Bureau by receiving forecasts, displaying weather and temperature flags, distributing copies printed upon postal cards by the logotype process, publishing them in the evening newspapers, and otherwise disseminating the information contained.

It is proper to state that, in addition to the distributing stations above mentioned, forecasts, State and local, are published daily upon weather charts and postal cards at nearly all Weather Bureau stations.

Accurate instrumental observations and correct deductions from the data obtained is the most important work of the Bureau, next to which is placing these deductions—forecasts—before the public, and the object of this discussion is to determine how this work can be performed with the least possible delay. For the reasons stated in the beginning of this article it is obvious that no rule applicable to all stations of the same class can be used, therefore I shall content myself with an attempt to point out a few cases where more or less time may be saved by rearranging the details of the morning work at stations where State forecasts are prepared or distributed.

The Bureau properly holds each individual forecaster responsible for his work, and necessarily it is left to the discretion of the forecaster at what stage in the preparation of the study chart he begins to write forecasts. Naturally the official desires to obtain and have placed before him all available data, but it is believed that a saving of some time might be effected without decreasing the value of the forecasts if he was required to prepare them for distribution before writing the synopsis. In fact, experience, observation, and hearsay evidence as to the methods practiced in making the study charts at some stations, suggest the idea that officials who make forecasts might save both time and labor of the man who does the clerical work on the general chart by making it themselves. By so doing the existing and probable changes in weather conditions would be fixed in their minds while entering the data and drawing the lines, and thus the necessity for much further study would be avoided and a saving of time in filing messages for distribution would be effected.

Primarily the saving or loss of time in placing State forecasts on the wire at forecast distributing centers rests with the official in charge, who apportions the work of the station to his assistants, but the first actual, and not least important, labor in time saving should be performed by the messenger. This labor consists in the preparation of sets of blank messages containing the addresses of all display stations in that particular district. By arrangement with the proper telegraph official the addresses may be so grouped that each blank may contain several, and thus the number of forecast telegrams to be prepared can be materially reduced. A set of these blank messages should be prepared during the afternoon of each day for use on the following morning. At distributing centers, when the station force is sufficient to admit of such arrangement, considerable time may be saved by having a man, equipped with a set of skeleton telegrams and a logotype or other duplicating outfit, in the operating room of the telegraph office every morning to make copies of the State forecast and immediately file them for transmission to their several destinations. By this method copies of the forecast addressed to every display station in the district could be filed for transmission within a period ranging from five to ten minutes after its receipt, whereas if the message should take its regular course, even if "rushed," from ten to thirty minutes' time, dependent upon the distance between the telegraph and Weather Bureau offices, would be consumed in delivering the message and returning copies to the telegraph office.

The service of distributing copies of forecasts by ordinary mail and rural free delivery service at forecast display stations being performed by displaymen, who cooperate with the Bureau without compensation, promptness in handling forecasts thereat depends largely upon the interest taken by the individual displayman. Close attention to the needs of the displaymen on the part of the section center in furnishing supplies, writing courteous letters of inquiry regarding their needs, requesting them to suggest methods for the improvement and extension of the service, together with occasional visits by a representative of the Bureau, are calculated to increase their interest in the work.

Much may be done in this regard also by furnishing the addressed forecast cards in packages containing one card only for each address on the displayman's list. The improved method in copying addresses recently introduced at most, if not all, distributing centers makes this not only possible without extra labor, but comparatively easy.

I repeat that it is not practicable to enumerate in this paper all instances where time may be saved during the preparation and distribution of forecasts, but it is hoped that the few pointed out may serve to illustrate what can be accomplished by systematizing the work at the several stations so that the whole time of every member of the office force may be profitably utilized during the "rush" morning hours, and to the end that the public may reap the benefit of our labors at the earliest possible moment.

DISCUSSION.

C. E. LINNEY: Mr. Blythe has practically covered the ground in his paper, but I wish to emphasize a few of the points which he gave.

You are all familiar with the manner of distribution by means of the logotype outfit and cards, also the other means of distribution after the telegram reaches the displayman, and I will not take up your time with a discussion of them, but wish to give you a few points on the method used at Chicago to secure rapid transmission of messages.

Several years ago, when we began to investigate the manner in which our telegrams were handled, we were sending the forecasts to the several section centers, which in turn sent the forecasts to the displaymen. We found that in a large number of instances telegrams from the section centers to the displaymen were sent from the section center back to Chicago, relayed there, and sent on to the displayman. This was especially the case with the near-by States—Illinois, Iowa, Wisconsin, Michigan, and Indiana. The loss of time ran from one to three hours. We then went to the Western Union officials with a complete list of displaymen and others receiving forecast messages within the Chicago district, and asked for the relay points on them. When these were received we prepared blanks accordingly, placing all points in each State which were relayed at the same point on one blank, and in some instances entire States were covered in this way. A duplicate set of these was furnished to the Western Union Company, with the information that we should begin to distribute messages after the plan at a certain date, which we did. If most of the points of a certain State to receive forecasts were relayed at one point, the message was written at the desk from dictation as the forecaster gave it, while if several blanks were required the messages were run off on the milliograph. We have thus been able to handle over 600 forecast messages in twenty minutes or less daily.

Additions to the lists or the cutting out of a name are simple matters, the telegraph company being informed of each change, the proper relay secured, and the town entered on the proper blank accordingly.

FORECASTS ON STREET CARS.

By Mr. N. B. Conger, *Detroit, Mich.*

The method of disseminating weather forecasts to the general public by posting them in a prominent position in street cars has met with great favor wherever it has been practiced, for in this way the forecasts meet the eye of a large number of people.

When the cards are posted in the cars by 11 a. m., they attract the attention of large numbers of people who use the cars thereafter, and thereby the information is disseminated to many of the homes of citizens for their use and benefit in a way that can not be readily accomplished otherwise.

In the city of Rochester, N. Y., the distribution of the cards to the cars is made by the switch tender located at the "four corners" where all the cars pass, and as each car goes by a forecast card is handed to the conductor, who immediately posts it in the proper holder at the front of the car. Thus in a short time all the cars are supplied with forecasts, and the patrons of the road have the full benefit of the forecast early in the day.

In Columbus, Ohio, the practice is to furnish the proper number of the cards to the barns or stations where the conductors hand in their reports, and as each conductor passes in his trip report he takes a forecast card from the packet before him and places it in the holder in the car. Either of these methods is practicable in most large cities. In the small ones the cards can be left at the terminal points in order that each conductor may be served as soon as he arrives.

The effectiveness of the distribution of cold-wave warnings in this manner can not be too highly praised. It enables the Bureau to place before the general public, and more particularly the householder, these valuable warnings as promptly as possible, and it spreads the information widely through the city and is more effective than any warning flag that may be displayed over the office.

This system is simply to be used in addition to the usual method of distributing the forecast cards by mail or messenger. The main point to be kept in view is the bringing of this information prominently to the eye of those who are not so liable to be in places of business where the cards are displayed.

It has been found that where this service has been in operation for some length of time it has become the feature of the service, and has been very favorably commented on by the general public.

The prompt distribution of the forecasts to points where the public can have ready access to them makes them of greater value, and this simple means employed in this direction has been found very effective.

The first distribution of forecasts by street-car service, to my knowledge, was inaugurated in Lansing, Mich., in 1888. The distribution was, however, accomplished by the use of tin symbols carried on the rear of the car, and was prior to the inauguration of the distribution of forecasts by the card system. It is not, however, claimed that it was then an original idea, for it was simply adopting the idea which had been in operation in Ohio for some years of displaying the forecasts by means of symbols on the sides of baggage cars on several of the railroads in that State.

In some cities it is possible that the methods governing the street car systems will not allow the prompt distribution of the forecasts on the cars, so that it would be necessary to station a messenger at a central point where he could reach the cars as they passed that point. The expense in this connection would be small, probably not equaling the cost of three telegraphic messages daily.

There is in connection with this method of distribution one very important point to be kept constantly in view, and that is, to obtain a rigid rule from the superintendent that the cards shall be promptly changed daily, and that under no circumstances should the card of the previous day be allowed to remain in the holder when the car goes out of the barn in the morning. The necessary regulations are very few, and with hearty cooperation between the street car company and the Weather Bureau official there need be no trouble on this score at any time. The proposition is worthy of attention in all large cities where effective street-car service is maintained.

DISCUSSION.

Mr. L. M. **PINDELL** (Chattanooga). I consider the display of forecasts in street cars an excellent means of disseminating the information, but the cards must be handled promptly and regularly. When the display was inaugurated on the cars in Chattanooga, I had considerable difficulty in getting the cards on the cars promptly. The officials of the road were eager to cooperate, but through lack of interest on the part of subordinates, the service was slow in being established. Now, however, the cards are displayed regularly and promptly. The letter carrier delivers the cards to the transfer agent, who distributes them to the conductors as the cars come into the station. The car service disseminates the forecasts better and wider in the city and suburbs than the newspapers, because a large number of people do not subscribe to papers. These people see the forecasts as they ride to and from their work. On small cars only one card is displayed, but on long cars one is posted at each end of the car. Not only are the forecasts, but also cold-wave, frost, and emergency warnings, displayed on the street cars.

Mr. J. B. **MARBURY** (Atlanta, Ga.). Ever since the inauguration of the daily weather forecasts, various methods have been devised for their presentation to the public. Some of these methods have been adopted until superseded by others; while some have been discarded as impracticable. The display of the forecasts on street cars, if it could be generally and successfully inaugurated, would certainly place the benefits within reach of vast numbers who probably would not otherwise see them.

This is not a new question, but one that has been agitated time and again for a number ot years past. The fact of its not having become general shows that there must be considerable opposition to the methods so far proposed for their display. So long as it is attempted to use the card and holder now in use I am sure it can never be universally adopted. Their appearance in the car is the objection raised by most car officials, who claim that the cards detract from the looks of the car. Another difficulty is the supplying of the cars with the cards in a prompt manner. I have with me a crude drawing of a device for displaying weather forecasts in street cars, and will try and make it as clear as possible, as well as give my plans for its use. The device is a metallic box or case about 6 inches long 4 inches wide and 1½ inches deep on the inside. At the top is a space 4 inches by 2 inches, on which is painted the words "Weather forecast for ———." Below are three openings extending across the face of the case and each about half an inch wide. Behind each of these openings is a cylinder, turned by a thumbscrew. On the upper cylinder are the days of the week; on the middle cylinder are the various weather conditions forecast—Rain, showers, rain or snow, fair, etc.—and on the lower cylinder are the temperature conditions—warmer, cooler, colder, cold wave, etc.

These display cases can be made in lots of 500 or more for about 75 cents each. Now, to defray this expense I added a slide at the bottom about 2 inches wide on which to place a display advertisement.

My plan for changing the forecast in each car is to telephone it to the office of the "starter," who would give it to each conductor or place it on his bulletin board. The change would be made by simply turning the thumbscrews at the side of the case. The forecast so displayed is for the ensuing day and would be before the public during the greater portion of the day of issue.

The forecasts may also be displayed in the elevators of office buildings in the same manner.

WEATHER SYMBOLS ON RURAL FREE-DELIVERY WAGONS.

By Mr. L. M. PINDELL, *Chattanooga, Tenn.*

In my opinion the Bureau should furnish tin symbols, in conformity with the flags now used, to the rural free-delivery carriers. The latter would, I am sure, gladly attend to the display, and would also distribute the "cards of explanation" to all the patrons along the routes. The routes leaving Chattanooga pass through sections where it is utterly impossible to reach the people by telephone, and heretofore they have been compelled to go from 3 to 8 miles for their mail. They have never had the benefit of the weather service or its reports. With the display of symbols on the wagon as it passes along the county highway the farmer in the field can see what the weather forecast is and arrange his plans accordingly. The symbols in use were purchased at a cost of $4.50 per set. They are 1 foot square, beveled all around to prevent bending, and riveted to an iron rod, each symbol except that representing the cold wave has two tin bands, into which the rod of the other symbol can slide and make the combination. Two iron pieces with holes are attached to the side of the wagon near the top, which hold the symbols. The farmers are very much pleased with the information given them, and insist upon its being continued. I was recently informed by a carrier that the display on the wagon was watched and looked for by the farmers with more interest and eagerness than their mail. We have discovered that the symbols are a little too heavy for the rods; when two are displayed together the rods are liable to break where the rivets pass through. It would be better, I think, if the flags were made out of japanned tin and of smaller dimensions.

CLIMATOLOGY OF FLORIDA WITH REGARD TO CROPS.

By Mr. A. J. MITCHELL, *Jacksonville, Fla.*

[Read by title.]

A lengthy monograpn would be necessary to fully discuss the climatology of Florida in its relation to crops. In area Florida embraces 58,680 square miles, mainly between parallels of latitude 25° to 30° north and longitude 80° to 87° west. The physical features of Florida are pronouncedly dissimilar to those of the other Southern States. The geological upheaval resulting in the formation of Florida bequeathed us neither table-land nor mountain from which to view ocean and gulf. On the contrary, the most elevated portion of the State barely reaches the dignity of a hill. Bathed on one side by the gulf and on the other by the ocean, the climatology of such a peninsula deserves more than passing notice. Already famed as the Riviera of America, holding out hope to the invalid and pleasure and comfort to the robust, Florida occupies a unique place in the Union of States. In one respect she has been the victim of her own good fortune, her commercial importance for a long time being obscured by reason of her reputation as a place of balmy air and friendly temperatures, whose virtues were supposedly paramount in her ability to give sunshine and warmth while other sections were influenced by subpolar conditions. But the investigating mind will ask: "What of her crops? Of these we would like to hear." To more easily comprehend the subject, in the absence of graphic charts, let us divide the State into three divisions, designating that portion north of the twenty-ninth parallel as north Florida, that portion south of 29° and north of 27° as central Florida, and that portion south of 27° as south Florida. Within the areas specified there is grown, to some extent, every staple crop produced by other States of the Union—the cereals of the West and Northwest, the fleecy staple of the South and central West, and the fruits of the Pacific coast—and, in addition thereto, many other products indigenous only to the peculiar soil and friendly climate of a subtropical region. In the study of climate with regard to crop production it would be a serious inadvertence not to consider soil temperatures. Adanson, the French botanist, states that the development of buds is determined by the sum of the daily mean temperatures, counted from the beginning of the year. Another authority concluded that the length of the period of vegetation is in inverse ratio to the mean temperatures; while Sachs, the greatest of plant physiologists, concluded that for each form of plant life there is a minimum, an optimum, and a maximum temperature.

It is obvious, then, even to the superficial thinker, that whenever the conditions are most uniform, by reason of equable temperatures and well-distributed precipitation, a decided advantage results, for the possibility of crop failures is thereby reduced to a minimum. The question of sunshine plays no small part, for actinic energy is an important factor in crop production.

Florida not being subjected to prolonged and severe winters, with great ranges in temperatures, her soil is always in a receptive state, and crop growth is rarely retarded to such an extent as to excite apprehension.

Let us study her crops seriatim.

Cotton.—Sea-island and short-staple are grown with great success some distance from the coast, north of parallel 29 and westward beyond the Apalachicola River. The section where ranges in annual temperature are not marked and where extremely low winter temperatures rarely occur is best suited for the growth of cotton. By reason of our mild winters and the early occurrence of the last killing frost considerable cotton is planted in March, nearly a month in advance of other sections of the cotton belt. The normal precipitation over the Florida cotton belt is about 15 inches for April, May, and June—the period of planting, germination, and chopping. The normal rainfall during

July, August, and September—the period of fruitage—ranges from 16 to 20 inches. Most of our precipitation comes in frequent showers, with intermissions of warm sunshine—ideal conditions for the advancement of cotton. Rainfall is much less during October and November, when the bulk of the crop is harvested. The average temperature during July and August, a critical period with the cotton crop, is practically 80°, while the maximum temperature is rarely 100°.

Cane.—Among other staple products of growing importance we may mention cane. Dr. W. C. Stubbs says that a dry, warm winter, followed by a moderately dry spring, and this, in turn, followed by a hot, wet summer, are favorable to maximum growth of cane. Also, that the mean temperature should range between 65° to 86° (winter and summer means), with an annual rainfall of about 60 inches. In setting forth the most favorable conditions conducive to cane growth, Dr. Stubbs was but stating the real climatic features of Florida. While the State, as a whole, is not given to growing cane, there is an almost endless acreage, beginning about parallel 29° and terminating at the sea, adapted to the industry. The soil is rich in vegetable matter and enjoys an annual precipitation of from 58 to 60 inches, ranging from 6 to 8 inches in the fall and winter—the dry season—to 18 and 20 inches during the summer. The normal sunshine is about 60 per cent. The normal mean temperature for January ranges from 60° to 70° and that for July 80° and above. The possibilities of Florida as a cane-growing State are the more important when we consider that our Government pays $100,000,000 annually to foreign States for sugar. Another fact, which I desire to repeat with emphasis, is that over the greater portion of this possible cane belt frost has never been severe enough to do serious damage, and that throughout the belt the period of the first killing frost of winter, whenever it occurs, is quite a month later than is the case in other cane-growing States—a factor of very great importance, allowing, as it does, a longer period for maturing.

Cassava.—Indigenous to tropical climates, cassava grows perfectly on reasonably fertile, sandy soils, and reaches its greatest perfection where it enjoys immunity from killing frost. The greater portion of Florida is adapted to the growth of cassava, by reason of the eight or nine months of freedom from frosts and the sufficiency of well-distributed rains.

Oranges.—With physical characteristics common to Florida, the success of the citrus industry depends on the range of winter temperatures. With adequate and well-distributed precipitation, and with winter temperatures not lower than 20° over the northern portion of the citrus belt, the orange industry is assured, for with the degree of cold indicated, or even less, its destructive effects are largely mitigated by protective measures. In 1893, with a minimum temperature of 24°, the orange output was 6,000,000 boxes; in 1895, with a minimum temperature of 14° at Jacksonville, the crop was 75,000 boxes. The winter temperatures influencing citrus growth during December, January, and February will be well understood by citing the mean minimum for January, which ranges from 50° to 60°, embracing the extreme northern and southern citrus belts. The lowest temperatures ever recorded over the section indicated range from 18° to 40°. The highest temperatures ever recorded at Weather Bureau stations were less than 100°, mostly 95°. The normal precipitation for January, February, and March ranges from 6 to 9 inches; for April, May, and June, 12 to 15 inches, with an amount a little in excess of this for

July, August, and September, depending largely on the number and near approach of tropical disturbances. The sunshine during winter months is about 60 per cent; during the summer it is about 50 per cent.

Pineapples.—The successful growth of pineapples is markedly dependent upon winter temperatures. Although strictly a tropical plant, it grows with great success unprotected along the parallel of 27°, and northward, under cover, as far as parallel 29°. With protection, pineapples can be grown as far north as Jacksonville. Its native habitat, however, is below the frost line. It is not to be inferred that plants can not withstand moderately cold weather. Light frost does no damage other than retarding growth, for it occurs quite frequently along the east coast, within the pineapple belt. It is only in cases of severe frosts and freezes that the pineapple crop suffers. An annual rainfall of 50 or 60 inches, the bulk falling during the spring and summer, is ample for the pineapple. Heavy dews, in the absence of rain, are of marked benefit. The present methods of protecting plants by means of lattice work was designed, primarily, for winter service, but it is found that the exclusion of intense insolation contributes to the improvement of the fruit; consequently many fields are now shaded during the hot days of June, July, and August. By so doing "scalding" is obviated and the fruit has a better flavor. The pineapple industry is centered in Brevard and Dade counties, along the Indian River and on Lake Worth, thence southward to the Florida Keys. The section enjoys an annual precipitation of 55 to 60 inches, with minimum temperatures rarely reaching the freezing point over the northern portion of the pineapple belt. The varieties of pineapples are the Red Spanish, Golden Queen, Smooth Cayenne, and the Abbaka. The pineapple industry is confined exclusively to Florida.

It will be sufficient to mention the vegetable, melon, and minor crops, in the aggregate amounting to millions of dollars, made possible by their propagation and growth in winter in our low latitudes, and bringing to the agriculturist and horticulturist a reward out of all proportion to intrinsic value. I may here remark that the fruit and vegetable grower of Florida considers the Weather Bureau an indispensable factor in his enterprises, and relies on it for timely warnings of frosts and cold waves with the same degree of confidence that he does the fertilizer which hastens the life and vigor of his plants.

The discussion of agricultural and horticultural interests would be incomplete without stating that the hot waves of the interior are felt with little severity on the lower South Atlantic. The uninformed will ask why this is so. The very conditions contributing to the ultra-equatorial conditions of the continental West bring during the greater portion of the time moderate temperatures incident to the prevailing easterly winds. Being under the influence of the permanent summer high-pressure area of the Atlantic, our agricultural interests are rarely influenced by the extreme heat of the Central West; on the contrary, our winds are of oceanic origin—refreshing to man and vitalizing to the vegetable world. Droughts involving total crop failure are unknown. The cool, rain-bearing winds of the Gulf and ocean give showers over Florida, while the increasing capacity of the air for moisture as it moves inland accentuates a droughty condition over more northerly sections.

SECTION 6.—INSTRUMENTS AND EXPOSURE.

ADDRESS BY CHAIRMAN, PROF. CHARLES F. MARVIN.

We are all here together for the general good of the service. This, I take it, is the primary object of the convention, and there are a great many things I would like to say to you, but you all see that time is very short, and I am satisfied this convention is peculiarly the opportunity of the station officials. This is their inning and we of the central office want to hear everything they have to say, so I am going to take but a minute of the little time that now remains to say a few words on my subject.

I am very glad Professor Moore said what he did yesterday about independent observatory buildings in parks or elsewhere. I knew the subject had been under consideration, and I am glad it is up for all of us to think about.

In inaugurating this great advance in our work I am afraid we will be, if possible, too modest in our ideas. No observatory should be put up now, or a few years hence, that is not the most perfect thing of the kind. The whole thing must be planned and worked out now on a line and in such a manner that the institution will answer all the purposes that will be expected of it ten or twenty years hence, and we must leave room for enlargement and expansion in directions we do not think of now.

In my opinion a small city lot will not do. We want an acre or two of ground at the least. Of course, in many cities, all the ground we need can be had gratis in all probability, but we must not skimp ourselves elsewhere when we have to purchase. Our present exposures are, alas, far from perfect in many instances, and the problem perplexes my division very much. I believe the only solution is the independent institution.

It goes without saying that the accuracy of the Weather Bureau records must be maintained beyond criticism at any price.

There is much more on these points to be said, but I will close with a word or two on instruments.

We are trying to give every station of consequence a full and standard equipment. Few of you realize, probably, how difficult this is with the funds available, but we hope all of you will be pretty well satisfied by the end of one or two more years.

A great many of you want tele-thermographs, which are not at present among the instruments regularly supplied. These registers are made abroad, and in their present form are not exactly suited to our needs. We are working on the problem ourselves, however, and I think a fine telethermograph will be one of the regular instruments at all important stations a few years hence. I can only ask you to be a little patient in the meantime.

We are about to make a radical change in the mounting of the maximum thermometer. In spite of our most rigid inspection and testing at the Central Office occasionally the mercurial column in some maximum thermometers "retreats" after the maximum temperature has been passed and an erroneous record follows.

All these errors are obviated by mounting the maximum with the bulb end higher than the top. This unfortunately necessitates lowering the thermometer to a vertical position when the reading is made. I will not attempt to discuss the merits of this departure at this time, but merely mention the matter for information. I obtained a proof of a new illustration showing this mounting just as I was leaving Washington, and pass it around for you to see.

DEVICE FOR AUTOMATICALLY RECORDING BEGINNING AND ENDING OF LIGHT PRECIPITATION.

By Mr. O. L. FASSIG, Ph. D., *Baltimore, Md.*

For many years a simple and effective device has been in use at Weather Bureau stations for indicating the occurrence of light precipitation, namely, a sheet of paper containing lines in copying ink exposed to the open air to catch the few drops of a shower, often too light to leave even a measurable trace in the rain gauge. The blurred lines upon the sheet where the rain has touched the soluble ink, while indicating the occurrence of rainfall, gives no clue as to the time of fall.

It occurred to the writer recently that the usefulness of this device might be extended by putting the paper in motion under cover excepting a small aperture for allowing the rain drops free access. To accomplish this purpose, an extra anemometer register which happened to be available was employed. The time lines and printed instructions upon the face of the wind-velocity sheets being in copying ink, served the purpose excellently. After placing the sheet upon the revolving drum a cover was placed over the latter, leaving only a small circular opening at the top about a quarter of an inch in diameter. The aperture was afterwards enlarged so as to extend entirely across the sheet of paper, still leaving the width about a quarter of an inch, while the number of lines upon the sheet was increased. The other parts of the register were, of course, also covered in order to avoid injury from rain.

This method may be employed with advantage at stations not supplied with the rather expensive self-registering rain gages in use at the more important Weather Bureau stations. By its use the frequent entries upon Form 1001 of the vague and unsatisfactory terms "rain began and ended during the night" may be entirely avoided. By increasing the rate of movement of the record sheet any desired degree of accuracy in noting the time of beginning and ending of precipitation may be attained. An equally satisfactory result is obtainable by means of the tipping bucket register only in case of an abrupt beginning and ending of a smart shower, as no record at all is made until one-hundredth of an inch has fallen. The record not only marks the actual time of the rainfall; it shows also the character of the fall, scattered drops indicating a light intermittent fall, a continuous blur indicating a heavy shower. The expense of the registering device is small, permitting its use at a large number of stations.

The method has been tested at the Baltimore station during the past few months under many different conditions, varying from a light sprinkle to a heavy shower, and at times of heavy continuous downpour. The results have been quite satisfactory, even with the crude improvised register described above. An instrument designed especially for the purpose would yield much more satisfactory results, and might profitably be placed in the hands of our voluntary observers, thus greatly increasing the value of the rainfall record.

The character of the records obtained is shown in the accompanying original record sheets.[a] Some of the imperfections noticed, such as the splashing and running of drops during a heavy shower, may be avoided by moving the sheets horizontally instead of placing them upon a revolving drum. The lines should be fine and closely drawn.

The method here described is of course of little value when used alone; taken in connection with a quantitative measurement, however, it affords valuable supplementary information.

DISCUSSION.

The **Chairman.** In regard to this paper I would like to say that while the idea is elegantly worked out and applied by Dr. Fassig, it has been frequently proposed at the central office, but thus far has never been tried. The subject will be further discussed by Mr. Oberholzer, who has also done some work in this connection.

Mr. **Oberholzer.** I have thought of this matter of indicating the beginning and ending of light rains for some time, and the idea of Dr. Fassig had suggested itself. I met the objection, however, of the rain spreading so much. I have thought of, but not completed, an electrical device by which drops of rain will be caught between bars of steel, completing a circuit and registering on a cylinder that revolves rapidly. I believe that can be practically worked out, but I have not completed it. I would like to talk about the importance of a registering rain gauge at every station. I believe that the rate of rainfall is almost as important as the amount. Frequently requests come to us at stations for the maximum rate of rainfall from people who wish to construct spouting, engineers who wish to construct culverts, etc. They wish to know how much water they should be prepared to carry off in a given time. If we do not have good automatic records, we can not furnish the necessary information. There should be some sort of table of rainfall, similar to the table on the back of the triple-register form. I have had some difficulty in getting the tipping bucket to register accurately every hundredth of an inch of rainfall, owing to dust in the city atmosphere. I have completed a circuit between the tipping bucket and the frame. I find that there is a good deal of difficulty in a smoky atmosphere from dust getting into the bearings of the tipping bucket and soiling them. In addition, oxide will quite readily form on the horizontal surfaces that form at the points at which the tipping bucket is supported, thus breaking circuit whenever the bucket tips. By putting an extension to the axle of the tipping bucket and fastening to it a coil of fine wire, which is further fastened to the frame, I find that we get successful records, even with oxidized contacts. Further, I believe the tipping-bucket gage should have adjustments by which the number of tips to the inch could be regulated. I find that in summer time, when showers come suddenly and heavily, there should be more tips. To correct the errors in heavy rainfall I screw out my adjustment, causing the gage to make more tips than otherwise. Such errors as may creep in, due to the corrosion of the bucket with age and the accumulation of dirt, would also be corrected by this adjustment. I found it quite successful on the gage I used for several years. I have thus been able to get accurate rainfall records when I know I got practically every hundredth of an inch that fell—within 2 or 3, or at most 5, per cent.

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[a] These record sheets have been reproduced and accompany this paper as Pl. XXXVII, figs. 6 and 7.

Plate XXXVII. Specimen Records of Beginning and Ending of Light Precipitation.

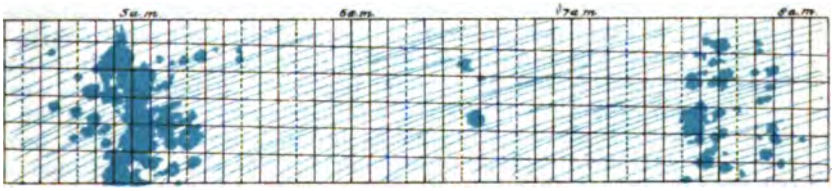

Figure 6. Very light shower.

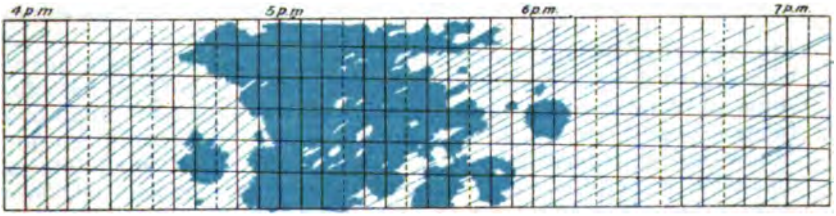

Figure 7. Light shower.

SUBURBAN METEOROLOGICAL OBSERVATORIES.

By Mr. A. F. SIMS, *Albany, N. Y.*

Professor Abbe has said:

> In these days, governments and private individuals vie with each other in stimulating physical, chemical, and astronomical science, and in the great universities laboratories and observatories have been equipped with the finest apparatus and provided with the most learned mathematicians and the most skillful experimenters, and it is well recognized that great advance is best made by men who to inherited gifts have added the great advantages of study and training. Meteorology has, to date, received but meager recognition, notwithstanding the fact that it is of great importance to mankind and is a science of highest utility.

Such a train of thought suggests that suitable buildings be erected in city parks as a method for carrying out the system of suburban meteorological observatories that it has for a long time been the desire of the Chief of the Weather Bureau to establish. In such schools of investigation, in line with philosophic methods and instruction, young men, after proper preparation, could perfect themselves in the study of meteorology; parents and school children learn something of nature's secrets, and professional men bring our science into use in their daily work. There, also, Weather Bureau officials, temporarily relieved from the large amount of executive work devolving upon them, could give time to experimental work and investigation in the higher and broader fields of scientific investigation for which they are qualified.

Model meteorological observatories should be constructed to enable us to get the proper exposure for our instruments, install a library where anyone who would engage in any line of scientific work, and especially of original research, could get a knowledge of correct principles and the best methods, and also of what has been already done.

For this special meteorological library, incontrovertible facts could be collected by a board of experts, and, as future research brings new facts to light, they could be filed for use in connection with the solution of complicated problems presented. A set of meteorological works and hand books of reference could be compiled that would treat of the elements in a popular tone, that would meet scientific demands for accuracy, and be clear and comprehensible to the ordinary understanding, and make teaching sound and thorough.

Within the walls of such meteorological laboratory, extensive pieces of research could be planned and promising investigations carried on. In such an observatory, meteorological theories, built up as facts accumulate, could receive further demonstration by experimental research or otherwise, and nature's processes reproduced, and effort made to learn more of her mysteries.

It is our especial privilege to aid in the sublime work of placing meteorology among the exact sciences. At present we are greatly hampered and trammeled and fail to fully understand meteorological phenomena, for the reason that we must base our knowledge of air flow and its physical condition on observations made on roof tops in the begrimed air of the populous portion of the city. Suburban observatory instrumental exposure offers a means whereby we can get rid of one of the most serious obstacles to exact observation, namely, diversity of exposure of standard instruments of precision.

The accurate measure of precipitation is of importance to meteorology and engineering; correct rainfall measurements could be secured in the experimental rain field in the observatory grounds.

In an experimental thermometer plot, thermometers could be exposed at various altitudes and data secured for use in connection with research into the history, effect, and method of protection from frost and application to the growing of plants in the most favorable locations. Within such plot we can collect data which, when properly correlated, will be valuable in connection with the study of temperature distribution in soil, and in the study of animal and vegetable life.

The present exposures and outdoor facilities of the Weather Bureau station at Albany, for all instruments, are decidedly unsatisfactory; the same condition obtains in other large cities. The progressive manufacturer constructs his buildings and arranges his factory to best suit the needs of his enterprise, places the best tools and appliances in the hands of intelligent men, and a superior product is the result. The same method of procedure applies equally well to our institution. The best is none too good for the work we have in hand.

In a number of suburban observatories, designated as schools of application, normal methods, in the meteorological training of our young observers, could be instituted, and thus, in course of time, would the young mind become the repository of many thoughts and be filled with desirable images. Such minds would connect, without confusion, the past with the present and penetrate into the future.

IS EXPOSURE AT WEATHER BUREAU STATIONS SATISFACTORY FOR ALL INSTRUMENTS?

By Mr. T. S. OUTRAM, *Minneapolis, Minn.*

All the instruments at Weather Bureau offices have their particular uses which could not be dispensed with by either the official or the lay forecaster. The records of some of these instruments might be said to have a commercial as well as a scientific value for the reason that they are much used in our everyday business life; therefore, to secure a proper exposure for all these instruments is an important matter. To obtain a good exposure for the wind instruments, barometers, etc., is generally a simple thing, but to secure a site for thermometers and rain gage where accurate readings are possible is very difficult, if not entirely impossible under the conditions governing the placing of instruments at our regular Weather Bureau stations. There is this to be said, however, and that is that the exposures are all very much the same, the whole country over, and that they are therefore comparable one with another.

The subject of the exposure of rain gages has been fully discussed by Prof. Cleveland Abbe, in a paper entitled "Determination of the true amount of precipitation and its bearing on theories of forest influences." In this paper Professor Abbe gives details of a varied series of experiments with rain gages under many different conditions, made by Prof. Joseph Henry of the Smithsonian Institute. Professor Henry finally concluded that the best exposure for a rain gage was in a pit so arranged that the mouth of the gage was not much above the level of the ground, thereby eliminating air currents and eddies which at greater elevations materially lessened the amount of rainfall caught by the gage. Of course the use of such a "pit gage," as he called this one, is out of the question at regular Weather Bureau stations, but could not the pit idea be carried out by having the gages suspended through a hole in the platform where they are usually exposed and in this way cutting off the disturbing air currents about the mouth of the gage? I think that the splashing into the funnel from the platform and the rising of air currents alongside the funnel from below the platform could be prevented in a simple way.

The time is past when our temperature readings are not regarded as thoroughly reliable, but it is a very common thing to hear it said that the "Government instruments are very conservative." It is frequently said that temperature records should be kept "where we live" and not away up there in the air, but the securing of true conditions on the street would be impossible where there are so many reflecting and radiating surfaces, and if such a record were made it would not seem correct for every individual, for there is in every person an ability to resist heat or cold which varies with his continually changing physical condition. There is then only one correct way to record temperatures and that is by placing our instruments in free air, sheltered from reflection and radiation, and this the Weather Bureau does within its limitations, but at most stations entire freedom from these influences is almost impossible. How much our moderate-temperature readings depart from the true temperatures I can not say, but I am convinced that our winter readings are too high, because the thermometer must be surrounded a good part of the time by a column of heated air rising from the hot buildings on which our shelters are placed. The greatest difference between the true temperature and that recorded will be when the wind is so light that the ascending heated column is not disturbed, and that is usually when the temperature is the lowest. While on the subject of temperature readings it might be well to suggest the slight coloring of the spirit in minimum thermometers intended for the use of voluntary observers; it would tend to prevent many incorrect readings.

THE MAXIMUM AND MINIMUM THERMOMETERS ARE TOO FRAGILE. CAN NOT EFFECTIVE PROTECTION BE DEVISED WITHOUT IMPAIRING SENSITIVENESS? SHOULD NOT ALUMINUM SCALES BE DISCARDED?

By Mr. G. R. OBERHOLZER, *Charlotte, N. C.*

Thermometers are, necessarily, delicate instruments. A material less fragile than glass that could be substituted for it in the construction of thermometers is not known now. Improvement looking toward rendering this instrument less liable to injury will naturally be confined to the method of mounting the glass stem and to the mount or back itself.

It would be difficult to devise protection for the thin glass bulb without, in some measure, impairing the ventilation, and, consequently, the sensitiveness of the instrument. The back now in use offers little protection against breakage of the stem, yet the free flow of air is, to some extent, impeded. It is questionable whether a thermometer should register, as the maximum of the day, the temperature of a puff of air that has been superheated by some roof top, or by the side of a building that seems to undulate in the glare of the afternoon sun. A sensitive thermometer will do this. It is believed that the Weather Bureau thermometer can be mounted so as to have necessary protection and lose nothing of its value as a meteorological instrument.

All the more recent thermometers are mounted on a strip of aluminum about six one-hundredths of an inch thick, and less than an inch wide. They are securely held in a groove, that has been stamped into the metal, by two clips, practically making the brittle glass a portion of the back itself. A slight bend of the soft metal will snap the stem; a blow on the back will be transmitted, with full intensity, to the glass; no shield is provided against violent contact with the glass from the front. A jar received by the bottom of the instrument tends to break the projection from the top of the glass stem, allowing it to slip down, breaking the bulb. A turn too much of the screws that fasten the stem to the mount will prove disastrous. Indeed, with the present mount, all blows or bends received by the back will be transmitted, with little diminution of intensity, to the fragile glass itself, and the back offers little protection from direct blows.

To remedy these defects in a measure a back was devised that I beg to offer for your inspection. Since it is the first design made, it is, of course, capable of much improvement. The back is of a semitubular form, which makes it at once light and strong, and also offers as ample protection to the tube as is consistent with reasonable ventilation. A blow received on the edge of this back will not be transmitted directly to the glass, but will be distributed by the elasticity of the mount. The glass tube is suspended from a brass spring fastened to its top, which tends to break the force of a blow on the top or bottom of the instrument. Brass springs are also introduced under the glass stem to break a jar from the back, and to give it an elastic fastening, making it proof against bends or twists. By this method of mounting the glass, blows that would ordinarily shatter it are received on a surface that will yield sufficiently to materially break the force of contact.

Aluminum, commended by its lightness, has been put to a great variety of uses, particularly in instrument making, shipbuilding, and for electrical purposes. It has not met with marked success in any of these directions. Electric furnaces that have been used in the recovery of the metal are being used to some extent in making calcium carbide, indicating that the use of the metal is not growing. The Navy Department some time since refused a consignment of megaphones because the mouthpieces were made of aluminum. The director of the British Aluminum Company says that in no case should this metal be exposed to the action of sea air or water without a protecting coat of paint or varnish. As a thermometer back we know how readily it corrodes, especially when near the coast. It most frequently forms a chloride, which is the familiar gray covering on our thermometers, rendering the scale practically useless, as well as unsightly. I have scraped these thermometers; used sand and emery paper; polished them with crocus and rottenstone; I have covered them with varnish and lacquer, all to little purpose. The objection to this remedy is that it will not stop the corroding, and the substitution of new thermometers will have the further disadvantage of breaking a quartet of instruments that are in accord, which is done with reluctance, however old the instruments.

The addition of copper to aluminum will make an alloy that is slightly heavier than the latter metal, but so much strength and durability results that it is used extensively in the arts. Recent experiments by the German admiralty indicate that aluminum bronze is not attacked by sea air or water if kept in contact with a metal that is electro-negative to it. Sir William White, of the English navy, has come to the same conclusion. It seems that it would be well worth while to try mounting aluminum-bronze thermometers on metal supports having this property.

The thermometer shown here has a back of enameled steel, which was courteously shaped and enameled by the National Stamping and

Enameling Company, of Baltimore. This back is at once durable and easily cleaned—indeed, it is nothing more or less than strengthened porcelain. It was found that any desired lettering could be fused into the glaze of this enamel, making it part of the back itself.

DISCUSSION.

Mr. P. F. LYONS (St. Paul, Minn.). In opening this discussion I shall simply confine my statements to what has been learned during my practical experience with the instruments in question at the regular stations of the national weather service for more than a quarter of a century, during all of which time neither breakage or even serious injury to any of those instruments has happened through either my manipulation or that of any of the observers at the stations where I have been on duty. Hence to the assumption, "The maximum and minimum thermomters are too fragile," etc., I must give a negative reply. They are not too fragile; but, perhaps, in selecting this topic for discussion, instruments suitable for sub-stations or volunteer stations, as well as for regular ones, were in view. As to the needs of sub-stations and volunteer stations, I acknowledge to having but a limited acquaintance compared with that of many of you who undoubtedly have had years of experience with them, and consequently you are better qualified to decide as to the pattern or kind of instrument best suited to them.

If the aluminum scales to thermometers were introduced with the expectation that the metal was not susceptable to discoloration, corrosion, or rust, etc., the same as brass and other base metals, the expectation has not been fully realized. In my experience, I have found that aluminum will not tarnish or blacken nearly so soon as brass, etc., but it will corrode after exposure for two or more years in cities where the usual soot, smoke, and other air impurities are abundant, and this deterioration is such that it can not be removed without the use of emery, and only then with some difficulty, whereas the other scales can be cleaned much more easily. If the object sought by the introduction of aluminum was a scale superior to the porcelain, I don't see that it has been attained.

The CHAIRMAN. Aluminum was adopted as advantageous because it goes easily through the mails. The postal regulations exclude matter weighing more than 4 pounds, and we often ship a batch of thermometers to stations that can be barely passed under the 4-pound limit. The express companies, I am sorry to say, break our delicate instruments relentlessly. There has been some improvement of late years, but we like a thermometer as light as possible, so we can forward it through the Railway Mail. That is one advantage aluminum possesses. Mr. Oberholzer pointed out the objection I made to his mounting. In order to expedite the work at the Central Office, and compare thermometers without defacing or soiling the backs, it is necessary to detach the glass, and we desire a mounting that facilitates this as much as possible, as, where we have 400 or 500 thermometers, taking off and putting back the glass tubes is quite troublesome.

SHOULD NOT THERMOGRAPHS BE FURNISHED TO VOLUNTARY OBSERVERS, THE RECORDS TO BE KEPT AT SECTION CENTERS?

By Mr. A. B. WOLLABER, *Portland, Oreg.*

In answer to this question, I would say that the furnishing of thermographs to voluntary observers and the compiling of the records thus obtained at the section center would, without doubt, prove a valuable addition to our rapidly growing fund of climatic information, besides affording an excellent check on doubtful temperatures as recorded by observers using maximum and minimum thermometers at voluntary stations.

The addition of a thermograph to the equipment of a voluntary station would also tide over breaks in the records caused by the observer's temporary absences, and an incomplete record, as every one knows, seriously impairs its usefulness. The annual means are of the greatest importance from a climatic standpoint, and they are only too frequently incomplete from this cause, and inquiries regarding the annual temperature for many districts remain unanswered, notwithstanding a station is maintained in that neighborhood.

In States where the regular Weather Bureau stations are wide apart, hourly temperature records at a few well-selected stations along the lines of railroads would add greatly to the usefulness of the records. It frequently happens that a Weather Bureau official is required to furnish to transportation companies temperature data covering the transit of perishable goods from one end of a State to the other, and, in such cases, hourly temperature readings would be of much practicable benefit. In a mountainous country, where freezing temperatures are an almost nightly occurrence, the records obtained by the use of thermographs might be of value to our forecast officials in the study of air drainage, frost, and cold-wave conditions, and any addition to our knowledge regarding these phenomena would prove of direct benefit to agriculture in general, and particularly to the horticulturist and market gardener in the spring and fall, and to the stockmen in winter.

It is not thought, however, that it would be advisable to furnish such delicate instruments to all voluntary stations, as many voluntary observers already have all they care to do in taking the daily eye readings required. In all States there are to be found observers especially interested in collecting meteorological data and who take great pride in their work, and these are the men who should be supplied with thermographs. It is also believed, in this connection, that a limited number of storm-warning display stations should be supplied with barometers or barographs, and with anemometers for recording the wind velocity. During the display of storm warnings vessels are frequently held in port, and on such occasions their masters are in close communication with storm-warning displaymen, and they quite frequently desire to compare their barometers and obtain information regarding the force and direction of the wind.

THE INTRODUCTION OF AUTOMATICALLY RECORDING RIVER GAGES.

By Mr. Weston M. Fulton, *Knoxville, Tenn.*

Not more than a century ago our rivers and their tributaries flowed for the most part through forests, broken only here and there by cleared patches which had been made by early settlers. The close of the century finds vast expanses of fertile and well-tilled fields where these forests once stood. These fields form a large portion of the agricultural lands of the United States. In fertility of soil they excel the uplands, and are sought by the agriculturist. Also many small towns and villages and a number of populous cities now stud the banks of our more important waterways. Early methods of transportation rendered these cities of great importance as commercial centers, and they have generally outstripped in wealth and population other cities which were not so located.

Without further remark it will be apparent to every thoughtful mind that the incentive for the study of river stages is to-day vastly greater than it was a century ago. The value of accurate water-stage records is increasing year by year, and the question which I now wish to advance for discussion is, Has the time not already arrived when automatic recorders should begin to replace the divided scale? If in 1873 our Government was justified in establishing a river and flood service, is it not now justified in increasing the accuracy and copiousness of the water-stage records by locating automatic-recording gages at the more important stations at least?

I take the affirmative side of this question for the following reasons:

1. Public interests justify this action.

2. The cost of erecting and maintaining automatic gages is not greatly in excess of that of the present gage.

3. Automatic records are of much greater value in making river forecasts, as well as in informing the public of water fluctuations, than are the once-daily eye readings.

(1) The late official census tells us that about 30,000,000 of people dwell in the Mississippi basin alone. The region which is drained by the Mississippi river and its tributaries embraces about 2,240,050 square miles, or 41 per cent of the total area of the United States, exclusive of Alaska and recently acquired territory. A sudden and decided rise of water in one of our important waterways, if unheralded and hence unexpected by dwellers in the lowlands, may result in loss to movable property exceeding in amount the annual cost to the Government for maintaining the entire river and flood service of the United States. These facts, together with many others already familiar to the general reader, will leave no doubt that public interests justify a careful study of water stages in rivers, based upon accurate automatic records.

(2) In the year 1897 I designed an automatic recording river gage which was intended to be constructed and installed in the Mississippi river at Vicksburg, Miss. About this time, however, official duties called me to Knoxville, Tenn., and the idea was temporarily abandoned. But the gaging of the Tennessee river at Knoxville, which came within the scope of my work here, soon revived the problem of constructing an automatic recording gage, and the plan was suggested to Mr. Allen Wade, who was a student in the engineering department of the University of Tennessee, and who was also my assistant. Mr. Wade evinced much interest in the idea, and in the spring of 1899 he and I undertook the work of constructing an electric recording river gage. The gage which was the ultimate outcome of these efforts has been described at length in the Engineering Record (New York), volume 41, pages 221–222, and in the University of Tennessee Record for October, 1899. It was installed in the Tennessee river at Knoxville on January 9, 1900, and records were continued until the ensuing summer. They were then temporarily discontinued for the purpose of remodeling the gage.

In the light of the experience gained from these experiments, it is believed that automatic gages of a similar pattern could be constructed and erected at an average cost of $100 each. Of course, in the larger cities, where the distance of the Weather Bureau office from the river and the closely built up city streets would render the cost of wiring excessive, the gage could be made direct recording.

From these considerations it will be seen that the cost does not prohibit the adoption of automatic gages.

(3) The records obtained from the gage referred to above indicate that the once-daily eye readings of water stages in the Tennessee River, which have been made at Knoxville during the past thirty years, seldom, if ever, indicate the exact time at which any flood wave arrived at this point, or the rate at which the water changed in height during the passage of the wave, or the maximum height reached. The highest and lowest monthly and annual records are, perhaps in many cases, in error by several feet. While this, perhaps, can not be said of the daily scale readings at stations in the lower rivers, where fluctuations in water level are less decided and less sudden than in the upper tributaries, it must not be forgotten that it is in the upper tributaries that floods originate, and for this reason, if for no other, automatic records there are of greatest importance.

With his knowledge of the value of the barograph records over the eye readings of the barometer, or of the thermograph records over the readings of the thermometer, no experienced observer can question the value of automatic river records over the eye readings.

RIVER GAGES IN THE UPPER MISSISSIPPI VALLEY.

By Mr. W. W. Carlisle, *Minneapolis, Minn.*

[Read by title.]

Not many years ago a long coast line and extensive navigable river systems were considered the greatest requirements for the prosperity of a commercial nation. Times and conditions have rapidly changed. The Father of Waters enters but lightly into the problem of commercial aggression. In the matter of domestic trade before railroads were born, river highways were invaluable and the plodding steamboat indispensable. Cities situated like St. Paul could not have existed without them, nor would there have been any excuse for their existence. The river trade on the upper river was then an ever-increasing success, and the steamers plying between St. Paul and St. Louis were numbered by the hundreds, but from the time of the arrival in St. Paul of the first railroad train the river business began to shrink. Boat after boat was taken out of the trade, until to-day, and in fact for twenty years past, a single line of steamers leaving St. Paul once or twice a week is all that remains of the upper river transportation. On the Chippewa, where formerly many light-draft steamers did a prosperous business, not a single steamer remains. There are other streams which the Government has faithfully and at great expense kept in a navigable condition which have the same history and the same pessimistic outlook.

Transportation on the upper Mississippi and on the smaller navigable streams does not appear to be profitable. The channels are too crooked and too shallow to allow successful competition with the railroads.

If, then, the introduction of an expensive system of automatic river gages is to be made merely and solely for the benefit of the river trade, basing an opinion upon the foregoing remarks, the upper river business does not seem to warrant the outlay. Yet there are, besides the steamboat interests, other claims to consider. For instance, as a mighty and, to a certain extent, self-purifying sewer for the cities along its banks the Mississippi is invaluable. It is just possible that at some future time it may become very necessary to possess accurate data of the water volume in order to know how much sewage per mile can safely be emptied into the river. The present system of gages seems hardly sufficient for furnishing records that could satisfactorily be used for such a purpose.

Then there is the utilization of the enormous energy of the rivers. Engineers must have certain facts upon which to base their plans, and are even now asking us for them. Above St. Paul, and in the smaller tributaries, we have nothing at all to offer them. As a sequence to natural economy, the time must certainly come when all possible water power will be used, and the Weather Bureau should be ready to furnish the engineers with all possible facts pertaining to river flow.

In the Chippewa river, already mentioned as profitless as a means of transportation, there are several points where apparently power enough might be developed for large manufacturing plants. Yet if an engineer were to request us to furnish him with a twenty years' record of the constantly fluctuating channel depth of that river in order that he might discover the actual average energy of the stream, or that he might construct an enduring dam at the least cost, or plan for the installment of the exact amount and kind of electric equipment we would simply have to turn him away with no information at all, for we have no gages in such rivers. These engineers have been compelled to base their calculations upon mere legend, and some costly mistakes have already been made.

In the Mississippi, below the St. Anthony Falls, a dam has been constructed, which, with a normal supply of water, furnishes power for the street-railway systems of both Minneapolis and St. Paul. It was only by costly experience that this company learned that sudden cold weather would arrest the flow of water; that on some cold-wave nights its power would suffer a shrinkage of something like a thousand horsepower, which, of course, had to be made up by steam. When we have sufficient data to enable us to successfully forecast the shrinkage of power which this and other water-power plants yet to be built will suffer during the passage of a cold wave, we will have added another valuable function to our Bureau. There are many things concerning river flowage we ought to know. For instance, all the available power of the St. Anthony Falls is used in the flour mills, and in low water auxiliary steam power has to be used. This low stage is hastened and considerably aggravated by the loss of the millions of gallons of water daily pumped into the city mains. We should have the facts in our possession, and we should be able to inform the city engineering department to what extent they must increase the headwater reservoir system in order to maintain the proper stage at this point. It would also be interesting to know how much water sinks into the earth through the bed of the river, and what effect vast headwater reservoirs may have upon the artesian-well flow.

In time a complete system of automatic gages will put us into possession of many facts that are now unknown. The proper gage to use must not only be automatic, but it must work in ice as well as in the open season. We want the full annual record of all streams that have a significant flow.

It is comparatively easy to construct a three-wire instrument recording feet and tenths, but the real difficulty lies in making the instrument work independently of waves and ice. It seems to me that this difficulty may be overcome as follows: Design the instrument to be worked by a heavy floater of, say 90 per cent specific gravity with counterweight. Inclose these weights in well tubing, and to the tube which contains the floater attach an ordinary strainer point such as is used in driven wells. Drive the tube into the river bed until the strainer is something like a foot under the sand. The water will then rise through the sand until it stands in the tube level with the outside surface. The water in the tube will now follow the rise and fall of the river, being perhaps half a minute behind. The level of the water in the tube being determined by the average pressure upon the river bed, the effect of the wave element will be nil. Such an instrument would be useful also in recording the mean rise and fall of the tides. To prevent the freezing of the floater we have only to pour down the tube a sufficient quantity of a non-freezing oil to depress the water surface below the depth to which ice forms.

SECTION 7.—AS OTHERS SEE US.

The CHAIRMAN (Professor Moore). The session this morning is for the purpose of closing up some details and hearing remarks from friends that are with us. I would especially like to hear from one of our guests, who is well known as one of the greatest statisticians of the country, and who was once in charge of the statistical work of the Department. I would like to hear a word from Mr. B. W. Snow, of Chicago, Ill.

Mr. SNOW. I had not intended to make any remarks, yet at the same time it is a pleasure to be present with gentlemen whose work I follow as closely as I do the work of the Weather Bureau. As some of you know, I pay special attention to the condition, the prospects, and the final results of the principal crops of the country, making that my sole business. I would not do justice to myself if I did not take occasion at this time to say that in this work I receive more help—more that is useful, in fact indispensable, in my work—from the weekly reports of the climate and crop service of the Weather Bureau than from all other sources combined. [Applause.] I conduct practically a service of my own, having a representative (and sometimes several representatives) in all counties between the Alleghenies and the Rockies; but a man who understands crop growth and the conditions which govern crop growth, if he be thoroughly intelligent, could take the weekly reports made by you gentlemen, and without another scintilla of data could frame an accurate judgment of what the crops would be. [Applause.]

The chair introduced Mr. Charles B. Murray, of Cincinnati, Ohio.

Mr. MURRAY. When I was coming here I felt glad of the opportunity to say something regarding the early history of the Weather Bureau, but inasmuch as that has passed beyond your interest I presume it is not now in order. But I want to say at the outset that the Weather Bureau service, as it took form in its application to the public interests, began in the Cincinnati Chamber of Commerce, and began with Professor Abbe. And I desire to express to Professor Abbe, through you, our appreciation of the valuable service he rendered to the country at large in the initial work that he performed there at Cincinnati. [Applause.] If you will allow me, I will suggest that I regard the Weather Bureau work as neither an invention nor a discovery. It was simply the creation of an incident, and that incident came about with operations of the Western Union Telegraph Company.[a] The Western Union Telegraph Company, in the prosecution of its work, had to receive such information as you are now receiving in regard to weather conditions, temperature, etc., to enable it to regulate the working of its wires. This was about 1868. The Western Union having inaugurated the collection of such information as would be useful at that office, Professor Abbe had the wit, the knowledge, and the discernment to see that there were elements which could be utilized in getting together information by which forecasts could be made. The prior object was not one of forecasts, but simply of records or announcements of weather conditions. The Western Union took up the work and inaugurated the issuing of a series of charts, with which, I presume, you are familiar. I have with me a copy of one of the old ones, of about 1869. The Western Union Company ultimately disposed of that, and the Cincinnati Chamber of Commerce, at its own expense, for a period inaugurated the whole work incident to the Weather Bureau endeavor. It secured the cooperation of Professor Abbe, and as a part of that work he went to Chicago to confer with the Chicago Board of Trade and get their cooperation. But the Chicago Board of Trade did not think there was enough of public interest and commercial interest to justify their going into it, and they turned the proposition down. But the Cincinnati Chamber of Commerce stayed with it. Professor Abbe's work was appreciated, and about 1869 the work was well inaugurated. By the early part of 1871 it had become so thoroughly established that the Associated Press asked the Signal Office the privilege of receiving in the morning—say, about half past 1 o'clock—these reports for transmission for the general information.

These were some of the items of the beginning of this work, and I could follow them up much further, but it is not necessary. I want to say, however, that while we have no basis of comparison of the value of one branch of the public service with another, we may readily accord to the Weather Bureau to-day the credit that, perhaps outside of the statistical work of the Treasury Department, there is no other service rendered by a Government bureau that, in my judgment, has a higher claim upon the consideration of the country.

Professor MOORE. We are more than pleased to have Mr. Murray with us. He is the editor of the Cincinnati Price-Current. We are glad to have him call attention to the primary work done at Cincinnati in the organization of this service. Milwaukee and Cincinnati can shake hands over that question. Professor Abbe in Cincinnati, with the aid of the Cincinnati Chamber of Commerce, and Dr. Lapham, in Milwaukee, with the agitation he carried on for years, were the two spirits that moved this Government to take the action that finally resulted in the convention we are holding to-day.

Now, before introducing Mr. LaVerne W. Noyes, of Chicago, permit me to say a word about him. He is the president of the Civic Federation of Chicago. He has some right to be with us because he manufactures windmills, though he does not like to have them called windmills—they are aermotors. He has made so many inventions himself, to improve the efficiency of the aermotor and get the greatest power out of a given wind velocity, that he has made his name famous all over the country as an inventor.

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[a] According to Professor Abbe, the collection of reports by telegraph began with the Smithsonian Institution about 1852, and its daily weather chart began shortly after. In May, 1868, he proposed a similar but more elaborate work to the Cincinnati Chamber of Commerce, which was carried on until January, 1870, by himself as director of the Cincinnati Observatory. From that time until May, 1870, he utilized the less expensive reports of wind and weather sent in by the telegraph operators. From May until November, 1870, the bulletins and charts were kept up by the officials of the Western Union Company.—[Editors.]

Mr. LAVERNE W. NOYES. Probably the daily work of no other body of men in the world is so closely scanned by so great a number of people of high average intelligence as the work of the United States Weather Bureau. That the work meets with such general approbation should be a source of great gratification to the workers.

It is not always a pleasing task to tell a person frankly how others see him, but in my case there is nothing to withhold. Most people look at your work from a single point of view, to wit, to know whether to set sail or to know how many hours yet remain to get the hay in stack or under shelter; to determine what kind of a bonnet to wear, whether to put on heavy or light underclothes, or whether it is to be a rain coat or one for warmth. It falls to the lot of few men to be called upon daily, before breakfast, to advise many millions of people as to what they should do or wear for the day. That you do not all become vain and spoiled by the adulation or execration and the universal daily and hourly attention which you get from millions of people is the best possible evidence that the civil service examination selects the right men.

There are, perhaps, a dozen people who, with me, have a different point of view of your work from that of the rest of mankind. We have to deal with the same element which mostly occupies your attention. We watch the records that you have carefully made for years to find where our field of action mostly lies. While you study the action of heat, cold, and electricity upon air masses, and what currents they are likely to produce, and what results are likely to come from those currents, we are largely interested in those currents themselves and what we can get out of them for mankind in general and for a few of the same kind in particular. While you note with great care the presence of a low, the direction of its movement, and the surrounding conditions, and foretell what is coming next, we are content to know that it exists and will surely raise the wind. What we loathe and detest is a stagnant and inactive condition of the atmosphere. We want something going on, and we would like it at about 15 to 18 miles an hour, but can do with it at about 10 miles an hour.

I am happy to report that there are very few days, indeed, in the course of the year in this region when we do not get the necessary air currents some time during the day, and I have no doubt that when your attention is properly called to these derelictions (seldom as they are in the vicinity of the "Cream City" or the "Windy City"), that defect will be remedied.

I doubt if the fact is fully realized that there is sufficient power which can be had for the taking, within 100 feet of the ground in a space 5 yards in diameter, to do all the work to be done on a 40-acre farm, from the sowing, cultivating, harvesting, thrashing, and marketing of the crops, to the rocking of the babies and the doing of all kinds of housework, and to furnish light, heat, and ice for the house, and electric light for the chickens to sleep by. It is certain that if the energy which passes through this space—5 yards in diameter and 100 feet high—were properly utilized in this region, the man who owns the 40-acre farm on which this ideal conservatory of wind energy is placed might avoid any physical exertion in carrying on the task of farming, and living, and being. Each man so situated would simply be the engineer who directs the application of the energies which the heavens furnish free and distribute to every farm and locality with a hand at times even too lavish.

All that is required of us is to furnish the means of converting the energy which passes over this piece of ground into some form, such that it can be stored, transported, and readily used. The unfortunate thing is that this energy, now being wasted, is somewhat shifty in its behavior, and rather diffuse and dilute. The energy utilized at Niagara Falls is not more sure in its annual quantity than the energy which wastes itself over the Dakota farm. The Niagara energy, however, exerts itself in one direction the year through, is very much condensed, and stable in quality and quantity from day to day. On the other hand, the energy to be derived from the winds at a given velocity varies with the pressure, the temperature, and other conditions of air, and varies in intensity from nothing to 100 miles an hour in succeeding minutes. But when the coal fields are gone, and the forests are burned up, and the oil fields are pumped out, there will always remain this universal force distributed almost everywhere on the face of the earth, which can be utilized for almost every known human need which physical energy can supply. The records which you are making to-day will, I have no doubt, contribute very greatly to this end. Either storage of compressed air, or the production of liquified air, or the storage of electricity will probably, in the near future, be largely employed to utilize wind power for many human needs, in addition to the countless uses already being made of these energies. By common consent the study and records pertaining to this universal source of energy have been left to you. You are, for the time being, the custodians of this great bounty to mankind.

The Agricultural Department has done wisely to publish investigations and records of actual tests of actual work being done in the field. The future will look to you for the final records, statistics, and information which will speed the day of almost universal use of wind power in the home, field, and farm, and for many larger services remote from the more reliable sources of energy. Much eloquence has been heard about "harnessing the lightnings of the sky," but here, gentlemen, in the subject of your study is a force at all our doors with which man can make the lightning at will and to order.

"The winds of heaven" are clearly what the future man will harness as his universal beast of burden.

Professor MOORE. Most of you gentlemen have had the pleasure of becoming well acquainted with Mr. E. R. Sharwood, the secretary of the Maritime Association of Philadelphia. He has been a member and an officer of that important organization now for twenty-five years, nearly as long as this Weather Service has been in existence, and he has always been a staunch supporter of the Weather Service.

Mr. SHARWOOD. As I sat and listened to the graceful flow of language of Professor Moore it seemed to me very easy to get up and say something on a subject so interesting to me, but when I learned that there was a gentleman present taking down what was said the thoughts I had took flight, and are now but a misty vision, like one of Professor McAdie's fog banks out over Lake Michigan. I shall not therefore undertake to rival the rhetoric of my good friend Professor Moore, but shall confine myself to one or two references to the Weather Bureau in its relations to commerce.

I am here by the invitation of Professor Moore, as a commercial representative of Philadelphia and as an officer of one of its commercial organizations, the Philadelphia Maritime Exchange. It has been the policy of this exchange for many years to identify itself as much as possible with those departments of the National Government which are more or less closely allied to commerce, notably the Light-House Board, Life-Saving Service, Coast and Geodetic Survey, Hydrographic Office, the Engineer Corps in its relations to harbor and river improvements, Bureau of Navigation, Marine-Hospital Service, and last, but by no means least, the United States Weather Bureau. It has been my privilege as an executive officer of our exchange to frequently meet with the heads of these departments, and my duties have been very much lightened and made very agreeable in consequence.

My first recollections of the Weather Service carries me back to the centennial year. In looking around me after I had been installed as secretary of the Maritime Exchange I was asked one day by a friend to visit the signal officer of the United States Army stationed in Philadelphia. I did not know what a signal officer was, but I went with him and was introduced to Sergeant Beale, whom some of you doubtless remember. He was a man of interesting personality, and I there and then received my first ideas of the work he was performing for the Government and commerce. Shortly after this, in the course of my duties, I visited Cape May, and there I found a gentleman, then representing the Signal Service, who is with us to-day, Sergeant Townsend. [Applause.] It is evidently not necessary for me to introduce you to Sergeant Townsend. I will only add that he and I exchanged confidences in 1876, and I now know him well and respect him highly.

The Weather Service has made rapid strides and stands to-day a monument to its builders. It would not be possible for me to speak of the scientific work of the Bureau, for I am not a scientist, but I can testify to the painstaking efforts of its officials, both in Washington and at stations I have visited, in placing at the disposal of commercial interests the material gathered through its very admirable system. The value of the Weather Bureau to the commercial and maritime interests of this country is hard to calculate. Storm warnings, and especially West Indian reports during the hurricane season, are of great interest, and it was my privilege at the last session of Congress to prepare a memorial setting forth the advantage to commerce of these reports, urging a liberal appropriation for their continuance.

In connection with the work of the Weather Bureau, I recently made an appeal to your chief to try and bring the service into closer relationship with the commercial interests of Philadelphia. Our fine Bourse building had been erected within a few years and all the commercial and maritime bodies had located themselves in this building. The Weather Bureau was situated in the Government post-office building, on the upper floor, far enough away from the commercial interests to cause the observer to look up in surprise when he received a visitor. Of course the Bureau occupied offices in this Government building rent free.

After discussing the matter with your practical chief, and after he had personally visited the Bourse building, it was arranged that the management would furnish free of charge space on the main floor and make electrical connections with the instruments on the roof and maintain the same if the Bureau would make an interesting display. This arrangement was soon carried out, with the result that we have to-day on the floor of the Philadelphia Bourse as interesting an exhibition of the possibilities of the United States Weather Bureau as it is possible to make. The commercial public have taken the matter up with zeal, and the daily visitors to the exhibit are on the increase. After the exhibit was installed Professor Moore was kind enough to detail Mr. Townsend to take charge of it, and instructed him to be on hand daily between the hours of 10 a. m. and 2 p. m., to follow up the good work and reply to the multitude of questions that of necessity would be put to him.

Classes from our various colleges and schools have visited the Bourse Weather Bureau exhibit, and it is the consensus of opinion that the Weather Bureau and the commercial and maritime interests of our city are closer together than ever before, and I feel sure from the remarks that I have heard expressed by prominent men that the interest will continue.

I have nothing more to add. It has been my privilege for a long time to enjoy the friendship of Professor Moore, and I feel sure that his energy and perception, fortified by his able staff, will find other outlets, and further cement friendly relations with the maritime and commercial interests of our country.

Professor MOORE. The Rev. Father Odenbach has shown great interest in our convention; he has been in attendance at all its sessions and his presence and his participation in our labors are greatly appreciated by every member of this gathering. We should be greatly pleased to hear further from him this morning,

Father ODENBACH. I have been waiting for this chance to speak to you, for on an occasion like this I have volumes to say. Still, to control the time as well as my own feelings, which might carry me away, my words will be few, but my heart will be in each and every one of them.

How do others see you? That is the question you ask me, and I will tell you how men of penetration, unselfish men, men who know you as I do, regard you. Let me voice their sentiments and render this judgment: Gentlemen, I find the members of the Weather Bureau to be men of a superior stamp as to intellect, as to interest, as to their fidelity to duty, and, above all, as to their great charity to an often unappreciative public. During these days of the convention I have been repeatedly tempted to pride at the thought that I have had the privilege, the honor, and the good fortune to meet with a body of men that reminds me so very much of the body to which I have the honor to belong. Gentlemen, I am a Jesuit, and I am proud of it; and here among you I find in this convention of Weather Bureau men that same earnestness of purpose, that same rigid discipline, that same self-sacrifice to duty to which I have been educated and by which I have been surrounded for almost twenty years. I have found this spirit in no other third instance either on this or the other side of the great waters.

This, gentlemen, is the impression I have of the Weather Bureau man as I have had the pleasure to meet him. From the chief down to the last boy in the service; from the man who lost his health and impaired his senses in sending a distress message on the Atlantic coast in a cold winter night down to the latest hero in the service who risked his life in the midst of a blast that carried off the barograph, so valuable to the service; these gentlemen, taking them for all in all, are men, and "who dares be more, is none." This must also be the verdict of all who know you as I know you; of all who know you enough to form a competent judgment. As to the rest, do as you please. The saying of nature's poet should be written over the entrance to every Weather Bureau office:

The evil that men do lives after them; the good is oft interred with their bones.

Write it there; write it in glowing letters. You can make use of it; you can apply it every hour of the day. [Applause.]

Professor **Moore**. There is one very important part of our work that has lately become prominent before the people, and that is the dissemination of our forecasts. There is no use in collecting information if you can't distribute it; no use in having forecasts of cold waves if you can not give them to the people that have property to be injured by cold waves. The press is our great medium of dissemination; but there are thousands of people who are out of reach of the press, and so there has grown up through the energy of the Post-Office Department a system of distribution to rural communities, and the man who originated that system and who is putting it into effect—the superintendent of the rural free delivery—has just entered this room. He has taken great interest in the distribution of the morning forecasts by his special carriers, and is furthering our work in that direction to the greatest degree possible. In fact, I am inclined to think that the Post-Office Department is the leader, and that whatever credit comes from it belongs mainly to the Post-Office Department rather than to the Weather Bureau. We are more in the position of simply cooperating by giving the forecasts than of being the leaders. We wish the credit to be where it belongs—with the Post-Office Department, and to a great extent to Mr. Machen himself. We want to hear from him.

Mr. A. W. **Machen**. After receiving your very kind and pressing invitation to be present at this gathering, I feel somewhat ashamed to come in at the eleventh hour. But the new service with which I am connected so engrosses the time of all those engaged in its management that it is scarcely possible for any one of us to leave his desk at Washington. The employees of the rural free-delivery division may be found early and late preparing the data upon which rural routes are being established at the rate of 30 a day.

I take it, from what I have learned from Professor Moore in several conversations I have had with him on this subject, that you are anxious to hear all about the rural free delivery service and to learn to what extent it may be used as a medium through which to scatter throughout rural districts the valuable information gathered daily by the United States Weather Bureau.

I doubt if the representative of the United States Post-Office Department at the Vienna convention of the Universal Postal Union in 1891 for one moment dreamed that within ten years the agreement signed at that time (and in honor of the United States, on the 4th day of July, 1891) would be so nearly fulfilled in this country. It was agreed then that as soon as possible all of the postal administrations which were members of the Universal Postal Union would establish a house delivery not only in cities and towns, but also throughout rural districts. Postmaster-General Wanamaker realized that the vast extent of territory of this country, much of which is sparsely settled, made the question of a house delivery difficult to handle, much more so than it would be in a small country with dense population and good roads. He therefore decided that thorough experiment should precede an attempt at universal free delivery. Congress was asked to appropriate $10,000 for this purpose. An appropriation of $10,000 was granted in 1892, available July 1, 1893. I had the honor to be superintendent of free delivery at that time and was ready to begin an experiment; but with declining revenues and increasing deficits confronting him, the Postmaster-General was loath to take any step that might further involve the Department and entail upon its future revenues what he thought would be too great a burden. The appropriation was not used, and so it was with the appropriations for the three succeeding years. In 1896 Congress included in the appropriation of $40,000 a mandatory clause. Prior to that time the use of the appropriation was optional with the Postmaster-General. In October, 1896, Postmaster-General Wilson ordered that steps be taken to carry out the wishes of Congress. The first route was established at Charlestown, W. Va., October 15, 1896, with many misgivings as to the success of the experiment. On the 1st of July, 1897, 43 routes were in operation. Congress then increased the appropriation to $50,000, and the new administration of affairs, seeing the great possibilities of the rural service and the benefits its introduction would bring the farmers of this country, ordered that every dollar of the $50,000 should be expended in broadening the experiment.

The following year the sum of $150,000 was provided, followed by $300,000 for 1899, to which a special deficiency of $150,000 was added, making a total of $450,000 for that year. Three hundred and ninety-one routes were in operation July 1, 1899; in 1900 there were about 1,200 routes. During the past fiscal year we established 3,100 routes, so that on July 1 we had 4,300 in operation, and by September 1 next (1901) 5,000 rural carriers will be delivering mail to 3,500,000 people in rural communities.

You who are engaged in a service in which experiments must be made from time to time can well understand with what the Post-Office Department had to contend at first. We knew not just what to do. I remember well when I asked the Postmaster-General to detail ten of the best inspectors in the service to come to my office and discuss matters with me before starting out to establish the first routes at points designated by the Department. When that meeting was called no one knew what to say. We wanted to establish rural free delivery. The first question asked me I could not answer, for the reason that I had had no experience myself in country delivery. How many families should be served on each route, how long should the route be, should all roads be traversed, what should constitute a reasonable day's work for the carrier, what salary should carriers be paid, what amount of bond should be required, and many others were the questions asked, to which the answers were nothing less than mere guesses. Everything about the new service had to be worked out gradually—evolved, so to speak. Four years ago it was in embryo; to-day it is a bouncing boy, growing into youth and manhood, soon to become the sturdy giant of the postal service.

You will understand, gentlemen, that with a constant clamor for this service from 250 Congressional districts it has tested the ability of the Department to the utmost to make a distribution of routes among districts and States to the satisfaction of all who have petitioned for them. Necessarily the service became scattered, and in its early days there was not a sufficient number of routes clustered in one locality to enable the Department to obtain results upon which to base a satisfactory report to Congress. Postmaster-General Smith was the first to foresee the necessity of a concentration of service, and in 1899 ordered the establishment of the first complete system of rural free delivery; that is to say, a service covering a whole county and displacing the old system of fourth-class post-offices and star routes. That county is well known to-day throughout the United States, especially by those who want the same kind of service—Carroll County, Md. This county has an area of 453 square miles, with a population of about 35,000, and to-day 45 rural letter carriers are delivering mail to between 7,000 and 8,000 farm families every day, and 90 per cent of it before 9 o'clock in the morning, for they leave Westminster and other distributing points at 6.30 a. m. The service displaced 66 post-offices and all the star routes in the county, numbering 33. The first quarter's results show that the saving caused by the discontinuance of post-offices and star routes, plus the increase in revenues actually accruing after the introduction of the service, came within $300 of paying the cost of the rural free-delivery service.

In Carroll County there are four traveling post-office routes. These differ from the ordinary rural routes in that they supply other routes with mail. The postal wagons, as they are officially known, are traveling post-offices in the full sense of the term, performing all the functions and providing all the facilities of post-offices, such as issuing and paying money orders, registering letters, selling stamps, etc.; in short, they are a post-office divided into four parts, hauled around through the country for the accommodation of the people. Last year the four wagons did a business equal to that of a Presidential post-office yielding a revenue of $4,000 per annum.

The county service will come gradually; we can not extend it as rapidly as we would like. In the county service alone do we see the perfect system of rural free delivery. Since the establishment of the Carroll County service we have established the service in half a dozen counties. It will soon be established in Delaware County, Ind., also in a county in this State (Wisconsin), one in Iowa, and one in Missouri. There is now one each in Pennsylvania, Tennessee, and Connecticut, and Niagara County, N. Y., will soon be completed. In the county service the amount of mail handled increases at once from 50 to 100 per cent, and the amount of mail collected from a route increases from 20 to 25 per cent. Remember that the collections from rural delivery routes mean a good deal more to the service, relatively speaking, than the collections in the large cities, because the farmer sends practically nothing but first-class matter—letters and postal cards; he sends no circulars, nor does he mail newspapers at the rate of a cent a pound, so that 95 per cent of the pieces of mail collected on a rural route bear 2-cent stamps, and it is the 2-cent stamp that makes up the great bulk of this country's postal revenues. Ninety per cent of the $111,000,000 produced last year comes from the sale of 1 and 2 cent stamps; so when I tell you the collection of this class of mail from the farmers in this country increases 25 per cent immediately after the establishment of rural free delivery, you can easily see that free delivery is bound to become a great factor in the increase of the postal revenues, and thus eventually become self-sustaining. To illustrate, let me relate what a well-to-do farmer of Carroll County told me when I expressed my belief that rural free delivery would be a great revenue producer. "Your statement," said he, "is not surprising to me. Before you established rural free delivery my postage bill amounted to $2 or $3 a year. Now every time the rural wagon comes over the hill my boys and girls think they ought to have a letter for it, and my postage bill is $2 or $3 a month."

This is practically true of many of the patrons of rural free delivery in other parts of the country.

To what extent can rural free delivery be used to distribute weather forecasts is a question which no doubt deeply interests all weather forecasters. Just before leaving Washington I had placed before me a statement showing the number of offices at which the Weather Service could now be handled by rural carriers. About a month ago a general letter of inquiry was sent to postmasters at rural free delivery offices, about 2,600. Replies have been received from about 1,800. Of the 1,800 points there are 464 which the carriers leave at 10 o'clock or later for their routes, so that it will be possible at these offices to use the rural carriers to distribute forecasts as soon as the Weather Bureau can arrange to get the information to the postmasters, who will be authorized to stamp the cards. Four hundred and sixty-four out of 1,800 is about 25 per cent. On the 1st of October there will be 3,000 points in this country served by rural free delivery. At the same percentage it is seen that 750 offices may be reached by the weather forecast system after that date. Averaging two carriers to the office means 1,500 carriers, who could deliver forecast cards to about 150,000 farm families. That will make a pretty fair start. There are a number of other places at which, upon investigation, we may be able to detain the carrier until after 10 o'clock.

The motto of the rural service is "Prompt delivery and quick dispatch." The mail must be given first consideration. It must be gotten out as quickly as possible, and by all means collections must be returned to the office in time for dispatch the same day. When the principal dispatch of the day is early in the afternoon, the carrier must leave early in the morning—too early for the forecast. In such cases, of course, rural free delivery can not be of assistance to the Weather Bureau.

Another question: Could not the rural carrier carry some kind of a weather signal? Your chief has suggested to the Department a system of displays on the side of the rural wagon. It is doubtful if such a system could be applied at this time. Rural carriers are not yet required to provide uniform wagons. Some use uncovered carts, some use buggies, and some of the more progressive buy well-made rural mail wagons. Of course under these conditions, with different styles of vehicles, a uniform display device could not be handled. But I see no reason why a rural carrier should not carry a flag signal or pennant. This, I think, would prove more efficient than a display device on the side of the wagon, because it could be seen at a distance. Farmers in the field would know at a glance what the weather probabilities were. I am speaking with full authority from the Postmaster-General, who takes more interest in this particular branch of the service than in any other, when I say that he wishes anything and everything done by which the rural free-delivery service may be made as nearly as possible a perfect convenience to the farmers of this country. He is therefore in full sympathy with any movement looking toward a complete cooperation between the rural free-delivery service and the Weather Bureau. He will authorize any rule or policy looking to that end, for under the appropriation act providing for rural free delivery he is given the greatest latitude and may promulgate any regulation that does not conflict with the fundamental postal laws.

By the exercise of this great discretion he allows rural carriers to become news agents and to sell newspapers on their own account to the people on their routes, so long as the papers have passed through the mails. Hence it is that the carriers are also allowed to peform private commissions for the people. While they must not act as agents for corporations, express companies, department stores, and the like, they are not denied the privilege of doing little errands for their patrons, so long as such work does not interfere with their official duties.

So you see, my friends, that with the heads of the two great Departments, the honorable Secretary of Agriculture and the Postmaster-General, working in perfect accord to a common end there can be no failure. The successful use of the rural free-delivery service as a medium for the distribution of weather forecasts is, I think, assured. It only remains for the Weather Bureau and the free-delivery system of the Post-Office Department to work out the details, and, judging from the earnestness which Professor Moore has already displayed in this matter, there will be no trouble whatever in perfecting a system by which not only the rural free-delivery service itself will become more popular, but your service will be made more far-reaching and beneficial to the people.

Every telling postal improvement marks an era in the history of the postal service. The introduction of the stamp in the early forties, the fixing of a uniform rate of postage in 1851, the inauguration of the registry system in 1855, of the free delivery in cities in 1863, the adoption of the postal money-order system in 1867—all were great strides in the march of progress during the past sixty years; but none of these is as far-reaching, as important, or as satisfactory to the people as the latest departure, the rural free-delivery service. The other features of the service are great conveniences indeed, but to make use of them, to be benefited by them, people must go to the post-office. The rural free-delivery service differs from them in that it goes to the people, and carries with it all the other facilities of the post-office, for, besides delivering and collecting ordinary mail, does not the rural carrier register letters en route, receive money for money orders, sell stamps and stamped envelopes, and, not least of all, deliver the daily forecasts supplied by the Weather Bureau? In short, is he not a traveling post-office?

Since the demonstration of the success of the rural free delivery I have often wondered why this great country discriminated against the rural communities as long as it did, and I am inclined to take some stock in the statements, made forty years ago by the opponents of city delivery, that the law limiting that service to cities of 10,000 inhabitants and over was nothing more nor less than class legislation. To what extent our farmer friend has been discriminated against may best be demonstrated by following a letter from the time it leaves the farmer's hands in Wisconsin until it reaches the merchant in New York, and the reply as it leaves New York and eventually reaches the farmer. After putting off writing for several days, on account of fatigue, the farmer finally writes his letter, hitches up the old gray mare, that has probably worked all day in the plow or the mowing machine, and drives 5, 6 or 10 miles to the nearest post-office, where he deposits his letter. From that point it is taken by star route to the railroad office, where it is put aboard the postal car. At Chicago it catches the flying mail for New York. When this train reaches
any a corps of experienced distributers board it, and make a dis-
tion of the mail for New York City by stations. The mail is
ved at New York, sent to the respective stations, and our farmer's

letter is hurried to its destination. It has from six to nine chances of delivery during the day, for the carriers in that city make from six to nine deliveries each day. It is delivered to the very desk of the addressee, is promptly answered, and the reply carried by the office boy to the nearest mail box, where it has thirty-two chances every day to be taken up by the collection service. It soon finds its way into the New York and Chicago railway post-office, reaches Chicago, and is sent out to the village for which it is intended. In many instances the train does not stop and the pouch is thrown off. If it is not drawn under the train and ground to pieces, the letter will reach the post-office, where it remains until the farmer calls for it. No letter carrier is there to hurry it out to the farmer; it must await some one from the farm. He may come in a week, or, if it is harvesting time, the busy season of the farmer, probably two weeks. Napoleon used to say that if allowed to lie long enough a letter would answer itself. Many a letter addressed to the farmer has answered itself, or in other words, has gone unanswered. All this has been changed by rural free delivery. The letter box erected along the rural route is a standing invitation to the farmer to write letters. He accepts the invitation; he does not hesitate to write, even though he is fatigued, because he knows the letter will be called for at the farm gate, and its answer eventually delivered to him at the same spot. Increased facilities bring increased business. The truth of this axiom has been fully demonstrated within the past two or three years by the rural free-delivery service. Collections from rural routes, as I have stated, increase from 25 to 40 per cent, showing that the rural communities are quick to take advantage of the facilities extended to them by the service.

Rural free delivery is the greatest boon ever vouchsafed the farmers of this country. It places them in touch with the outside world, keeps them posted on current events, causes improvement of roads, enhances the value of the farm and farm products, and takes away from farm life the monotony and social isolation which is largely responsible for the desertion of the farm by young men who seek the excitement of our large cities. Rural free delivery, in short, is the city reaching out and clasping hands with the country, and bringing her country cousins into a closer and more satisfactory relationship.

Rural free delivery is no longer an experiment. Although it is only four years old it has already become an assured, permanent, and expanding branch of the postal system, and it is only a question of time and executive celerity until all the people may have their mail service at their very doorsteps.

There is no doubt in my mind that eventually rural free delivery will solve the question of good roads. Good roads are indispensable to an efficient rural service. This was brought forcibly to the attention of the Department last winter, when it became necessary to suspend the service on a number of routes on account of the impassable condition of the roads. While the actual number of suspensions of the service was, comparatively speaking, quite small, there was a large number of cases in which the service was performed with great difficulty and much delay. The rural carrier can not possibly make regular time and perform efficient service over poor roads, particularly during the winter and spring months. Recent official inquiries disclose the fact that a portion of the roads of at least 1,000 of the 4,300 routes in operation July 1 require some repairs. The Department is now advising road supervisors and other interested officials that the lack of care given to the roads covered by rural routes will, if continued, endanger the permanency of the service, and it is the hope of the Department that a great number of the roads will be repaired before winter weather sets in.

One can not speak of rural free delivery without mentioning one whose name will be forever indissolubly connected with that service, for to Postmaster-General Charles Emory Smith is due the credit of bringing this new feature of our postal system out of the stage of experiment and uncertainty within a very brief period, and placing it on a permanent and most satisfactory basis. He has given this branch of the service more than any other his very best thought and attention; he has been equal to every emergency, and cutting away the red tape that too often impedes official action, has insisted that promptness, speed, and efficiency should characterize the introduction of the rural free-delivery service. Although the details of the service are intrusted to his subordinates, Postmaster-General Smith is at the helm, his is the guiding hand in the whole undertaking. The popularity and efficiency of the rural free-delivery service to-day prove the efficacy of his plans.

I can not close this somewhat rambling talk without referring to the very generous treatment given the rural free-delivery service in the Agricultural Department's Yearbook, and to assure the honorable Secretary and his associates that it is greatly appreciated by the Post-Office Department, an assurance his colleague, the Postmaster-General, has doubtless given him ere this. The great advertising which the Agricultural Department has thus given the service will, I know, be felt by my office when the greatly increased number of applications come pouring in as a result.

To Professor Moore and his associates in the Weather Bureau I wish godspeed in the great work in which they are engaged, and to assure them that the Post-Office Department stands ready to cooperate with them to the fullest extent to advance a service which carries with it such great benefits to the people.

Professor MOORE. It might be well to note that the director of our Maryland service reports that he gets his mail reports from Carroll County quicker and more uniformly than from any other county in the State.

We have heard several times from our good friend from Philadelphia, but we shall not regret, I know, hearing one word more from him before this convention closes. I call upon Mr. Harvey M. Watts.

Mr. WATTS. I thought I was to be left off this morning, and I feel that all I would like to say would be "Amen!" to what Father Odenbach said, and add "In secula seculorum!" But last evening in the papers I was quoted in a slightly ungracious way, which may be misunderstood by many here. I was talking of the position of the scientific man and his smaller monetary return for his work as compared with people in commercial life. Then I cited this convention as a remarkable one, solely concerned for the work it may do, and with no other object for existence. There have been no committees here on "more pay and shorter hours." The convention indeed has been given over to planning such extra work and investigations, in addition to the regular duties, that it seems to me the Weather Bureau men will need a twenty-four hour day to accomplish the tasks they are setting themselves. That, I think, is true of no other department of the public service of the United States. There is another thing wherein this service differs from all other departments of the public service. You are not, like other employees, kept away from the public. You are under daily criticism. The Army and Navy came before the public in 1898 after thirty years of innocuous desuetude, and have had nothing but quarrels ever since. Here is the Weather Bureau every day under criticism. I do not believe much in adages, but there are two adages that I find have been disproved by this convention. One is that familiarity breeds contempt. I have found that this is not the case. On the contrary, the more I know of Weather Bureau people the greater respect I have for them. The other adage is that ignorance is the mother of admiration. I have never believed that. It is the stepmother of admiration. The greater knowledge you have the more you admire. So I will say that the more I know of you, the more I admire as well as respect the splendid earnestness of the work going on all through the United States in connection with the Weather Bureau.

It has really been a very great pleasure to me to be here, and I speak from the heart in saying so.

Professor MOORE. We had with us this morning Mr. McCurdy, of Chicago, who is one of the best-informed men in regard to lake marine matters, and especially lake marine insurance, in the country. I regret that business of importance has required his unexpected return to Chicago, but I am informed that before he left he prepared a few remarks and requested Professor Cox to read them to the convention.

Professor COX. Mr. McCurdy has asked me to express to the convention the great pleasure and profit that he has derived from his meeting with us. He said that he would like to give a word of encouragement from the underwriters, who fully appreciate the importance of the Weather Bureau and who are desirous of cooperating in the work of saving life and property at sea. Before leaving for Chicago, Mr. McCurdy prepared the following brief remarks, which, with your permission, I will read:

> No longer can we account for the diminution of disaster on the lakes by saying we do not have the old-fashioned storms of the times of our fathers, but rather that we have timely warning of the approach of heavy weather, and the prudent master of the present heeds these warnings and remains safely in port.
>
> Disaster from stress of weather at one time on the Great Lakes caused 75 per cent of the loss, while to-day stress of weather damage has fallen to less than 25 per cent. and the principal cause of damage is confined to collisions, which nearly always occur during calm weather.
>
> We may concede in the superior construction of the modern steel ship an ability to withstand an ordinary storm, but here again we find a class of property of high value, very profitable to the owners, which neither owner nor master cares to imperil by taking an unusal hazard, and these men are quick to grasp the importance of an intelligent service like the United States Weather Bureau, and are the firmest believers in its necessity. The sailor, whose life is one of toil and hardship, has a voice of thankfulness for the Government that maintains a department that makes life a little more worth living.

Mr. Prof. MCADIE. This has been such a happy convention that I do not want to even suggest the possibility of another, but I do wish you would come to San Francisco, if it be possible. I wish it so much that I will not ask you to come—the things that are nearest and dearest to you in this life had better come of their own accord—but if you do come, you do not know how much it will please us. I might tell you some pretty stories about the "wild and woolly West," but perhaps this little incident will do for many others. Last night at the Press Club one gentleman from the Cream City was telling me of the great things that are to be seen on the Pacific coast. For instance, he said they took him down to Santa Cruz and showed him the big trees, and if there is anything on earth, he added, that you will lift your hat to, it is one of the big trees. They had told him down there that these trees were about 350 feet high and some 8,000 years old. Now, I do not know what may have brought about the transition, but he told me that the trees were 8,000 feet tall and three hundred years round, and the strangest thing was that, owing to the Milwaukee Press Club's hospitality, I was rather inclined to agree with him.

Mr. MURRAY (of Cincinnati) advocated the holding of the next convention in that city, saying that from the early work of Professor Abbe and the Cincinnati Chamber of Commerce there was a certain appropriateness in the Weather Bureau officials meeting in Cincinnati.

Professor MOORE. Gentlemen of the convention, we are honored this morning in having with us the Secretary of Agriculture, who has done so much to build up and extend the Weather Service. I want now to introduce to you Secretary Wilson, who will say a word to you.

Secretary WILSON. I am greatly pleased to meet you. There is no bureau in the Department of Agriculture in which I take more interest than I do in the Weather Bureau. It is a bureau that never rests content with its achievements; it must be different to-morrow from what it is to-day. It is a bureau that has no counterpart or likeness throughout the civilized world. It is an American institution that steps out along progressive lines for the purpose of doing good to Americans and American property. [Applause.] I need not attempt to flatter you, because Mr. Moore has been doing that, but I must say that I have looked in the faces of some bodies of gentlemen in my time, and I think this pleases me as much as any I have ever met. I may as well admit here in your presence that I am more exacting regarding your conduct than I am regarding the conduct of any other bureau in the Department. Anything done by a Weather Bureau man that tends to interfere with safety and progress can not be overlooked or forgiven. We may give a second chance to the man who steps aside in other bureaus, but the policy regarding you is remorseless, because the lives of our people and the property of our people are in your keeping, and you must be, as you are to-day, gentlemen of education and character. But I want to say, on the other side, that, being so exacting with the men of the Weather Bureau, I am anxious at all times for the advancement of the Bureau, and the advancement of each of you connected with it. Nothing gives me more pleasure than to be able to do something to gratify a Weather Bureau man and show him that it is the intention of the Administration of President McKinley, who looks so carefully into the details of everything (and people never know about it), whose eye never closes when the good of the United States Government is to be considered, to reward merit. I am glad you are making such progress. The time is coming when the American forecaster will go around the world; the time is coming when we will send a message every morning to every producer and tell him what we know about the weather, and when we will send a message after every ship that flies the American flag and tell her what she is likely to meet during the day. [Applause.]

Professor MOORE. Gentlemen, this seems to complete our program. In closing this convention I wish to say that the one thing that impresses me more than any other is the feeling of good will and good-fellowship that prevails in this convention. Here are over 100 of the supervising officers of the Weather Service, each one in rigid competition with the others—for our service is one in which the "survival of the fittest" is the principle exemplified. Our object is the welfare of the whole, not the welfare of the individual. It is the betterment of the service we aim at, and how to make this Bureau of greater and greater use to the people and more satisfactory to our Secretary, rather than individual preferment. Under such a system you are at all times in competition the one with the other. Nothing has done more to raise the standard and tone of this convention than the system of examinations that our Secretary has authorized me to put into effect. But notwithstanding this competition, which is really one of emulation as to who can best serve, I know of no factions in this convention. I know of no strife, except that of honorable emulation—that emulation which shall make the Weather Service still better and more useful to the American farmer and the mariner. This to me is one of the most pleasant things in regard to this convention. Not a man here has spoken a word against another. There is good will; there is bonhomie in the air. You assume great responsibilities with salaries that, although they have been greatly increased by our Secretary, are still small. You are part of a system which, through many ramifications leads up to the Central Office, and from the Central Office of the Bureau on to the Secretary. At headquarters there is the same feeling of good-fellowship that prevails among you. It is pleasant to say that we dwell together in peace, for peace means efficiency. Where there is strife there is inefficiency, for energy is frittered away by useless contention.

I declare this convention closed.

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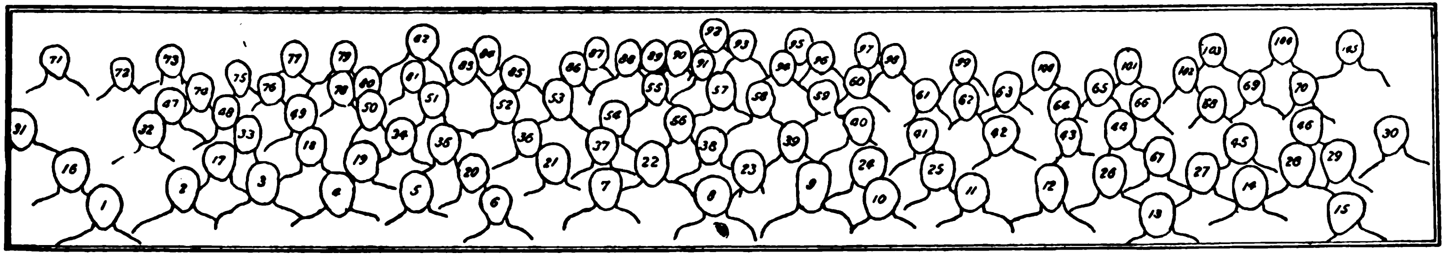

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U. S. DEPARTMENT OF AGRICULTURE.

WEATHER BUREAU.

BULLETIN No. 32.

HURRICANES:

ESPECIALLY THOSE OF PORTO RICO AND ST. KITTS.

BY

WILLIAM H. ALEXANDER,
Observer, Weather Bureau.

Prepared by direction of WILLIS L. MOORE, Chief of the United States Weather Bureau.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1902.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Chief of U. S. Weather Bureau,
Washington, D. C., January 11, 1902.

Hon. James Wilson,
Secretary of Agriculture.

Sir: I have the honor to submit herewith the manuscript of a paper entitled "Hurricanes, especially those of Porto Rico and St. Kitts," by Wm. H. Alexander, observer, United States Weather Bureau, and to recommend its publication as a bulletin of the Weather Bureau.

This paper has been prepared by my direction in the belief that it will be useful and instructive to the inhabitants of Porto Rico. Mr. Alexander has distinguished himself by his activity in studying the climatology of that region, and the data collected in this paper are undoubtedly as reliable as it is practicable to make them.

Very respectfully,

Willis L. Moore,
Chief United States Weather Bureau.

Approved.
James Wilson, *Secretary.*

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INTRODUCTION.

The atmosphere is one of the most fruitful fields of research in the whole domain of modern scientific investigation. No relation could be more intimate than that which exists between the air and all forms of life upon the earth. It should therefore be our ambition to so study the physical conditions, the movements, functions, and laws controlling the phenomena of the atmosphere that we may arrive at an intelligent appreciation of the forces that preside over the changes of the weather and the seasons and that dominate the very existence of mankind. In recognition of an awakening public interest, governments and institutions of learning have in recent years expended large sums of money to facilitate investigations along these lines. The possibilities of this new field of study have attracted to it some of the master minds of the age, who have devoted their energies to systematizing and advancing our knowledge, and to-day we find meteorology not only recognized as a science, but as one of unquestioned practical value, commanding respect and attention from thinking minds everywhere. We no longer regard the atmosphere as a region of mystery and lawlessness, but we look upon every atmospheric phenomenon as a result of laws as uniform and inexorable in their operation as those that bring the apple to the ground or guide the planet in its orbit. Where may we find lessons more practical or more suggestive, problems more interesting or more complex, manifestations more beautiful or more sublime than in the study of meteorology? The subject is vast, and our interest in it is direct and permanent, as well as real and universal, for truly "in ea vivimus, movemur et sumus."

The following pages are devoted to a brief consideration of a single phase of this vast subject, viz, those frightful atmospheric disturbances commonly known as hurricanes, which develop to gigantic proportions and cause appalling destruction of life and property.

Tropical hurricanes occur at certain seasons of the year in the Phillipines, East Indies, China Sea, the Indian Ocean, and the West Indies; they move thence into adjacent parts of the earth, but the greater part of the globe is practically free from their visitations. There is a similarity more or less distinct in the geographical features of these well-known hurricane regions which is worthy of study: Each has on the west a large continent, the coast line of which extends more or less nearly from north to south, is indented by gulfs and bays, and has to the east of it a vast sea containing numerous islands. "But of all the cyclonic regions," says Dr. Viñes, "within the intertropical zone the one which more perfectly and grandly combines all these conditions is the great 'Bay of North America,' with the wide Atlantic Ocean extending to the east as far as the coast of Africa and to the northeast as far as the coast of Europe and the northern seas. In my opinion, this contributes much to the grandeur and regularity of the immense paths of the West Indian cyclones (hurricanes)."

The hurricanes, or typhoons, of the China Sea may occur at any time from July to November; they usually begin east of the Philippine Islands and move first in a direction between west-northwest and west-southwest.

The region known as the Indian Ocean extends on both sides of the equator, and may very properly be said to embrace two hurricane regions, one on the north and one on the south side of the equator. So far as known, however, no hurricane ever moved across the equator. They may occur, and in fact have occurred, on the same meridian at the same time, but on opposite sides of the equator. The region north of the equator has two hurricane seasons, one in April and May and the other in October and November. South of the equator, in the Indian Ocean, hurricanes occur from January to April; these usually originate at about 10 degrees south latitude, move to the west-southwest until south of Mauritius, then take a more southerly course, and when about 28 degrees south their paths recurve to the southeast.

The hurricane season of the West Indies begins annually about the middle of June and lasts until the first of November. The origins, movements, and physical features of these West Indian hurricanes are the subjects of the following discussion, the aim being to present the facts in such a brief, simple manner as to enable one to get a correct knowledge of the essential characteristics and the most prominent laws relative to these storms.

In the preparation of this paper frequent reference has been made to the following publications: Physics, by Watson; Elementary Meteorology, by Waldo; The Atmosphere, by Flammarion; Cyclonic Circulation and the Translatory Movement of West Indian Hurricanes, by Viñes; West Indian Hurricanes, by Garriott; Handbook of the Hurricane Season, by Westerby; Chronological History of the West Indies, by Southey; History of the West Indies, by B. Edwards.

This memoir was originally prepared in 1899 and submitted for publication early in 1900: portions of it were quoted in the general memoir on West Indian hurricanes by Prof. E. B. Garriott, (W. B. Bulletin H.). It was then referred back to me, with instructions to prepare a special memoir on the hurricanes of St. Kitts and Porto Rico for distribution in those islands. The present manuscript has been revised by Professor Abbe, who has also read the proof sheets.

CHAPTER I.

THEORIES AS TO THE ORIGIN AND MOVEMENT OF ROTARY STORMS.

Unfortunately many of the terms used to designate the various kinds of atmospheric disturbances are not used with all the precision that is essential to clear conceptions and logical thought. This loose, indiscriminate use of terms leads to confusion in the public mind, resulting in a depreciation of the real practical value of our existing knowledge on this subject and of the efforts at advancement along this line. In view of this fact, therefore, we will first explain certain terms as they are now understood and generally used in the official publications of the United States Weather Bureau and as they will be used in this Bulletin.

1. *Cyclone* (Greek *Κυκλος*, a circle).—This term was originally applied to the circular movements assumed in connection with the old "law of storms," but as now generally used it is applied to all kinds of atmospheric disturbances characterized by an area of low barometer about which there is a movement of the air inward spirally toward the center. It is applied equally to severe hurricanes and typhoons and to the general areas of low pressure or the barometric disturbances of slight intensity but of vast proportions, whose diameters vary from several hundred miles to a thousand or more. These latter disturbances properly belong to the temperate zone and occur at all seasons of the year, being decidedly more vigorous in winter than in summer. They enter the Pacific coast of the United States from the northwest or southwest, and crossing by well-known paths make their exit in the vicinity of the Gulf of St. Lawrence. The value of the general weather forecasts for Canada and the United States depends very largely upon a correct analysis of the nature and relation of the various forces involved in these storms.

2. *Hurricanes, typhoons, or baguios.*—These are often called tropical storms, but are more correctly storms of intertropical origin and are sufficiently distinctive and are certainly of sufficient importance to entitle them to retain their distinctive names. Those originating in the Atlantic and passing over the West Indies or near the Atlantic coast of North America, or over the Caribbean Sea and Gulf of Mexico,

have received the name of hurricanes. Those visiting the Pacific, the East Indies, the Indian Ocean, and the coasts of Asia are known by the name of typhoons. The Malay term baguios, as used in the Philippines, is also now recognized. These storms are essentially the same as regards the manner of formation, movements, and general physical features, the. only significance attaching to the different names is geographical. These names come down to us from the distant past and possess an historical value which alone entitles them to a permanent place in meteorological literature, and if used consistently, as above suggested, no better terms need be desired. The term cylone can be used as a general name for all whirling storms.

3. *Tornadoes.*—The term tornado, when properly used in the United States, applies only to a very small whirling storm, but one that is intensely violent and destructive. In fact, tornadoes are dreaded in the United States even more than hurricanes, as they are more dangerous and more numerous, although of far less extent. They occur in all parts of the region east of the Rocky Mountains during the spring and summer months, and occasionally in the Southern States during the winter months also. A waterspout at sea is analogous to a tornado on land but is usually far less violent, still it is much dreaded by sailors. It may sometimes happen that one cloud will produce at the same time a number of tornadoes or waterspouts. It has been noted that as a great cyclonic area sweeps across the United States, especially after it passes the Rocky Mountains, the conditions prevailing in the southeastern quadrant of the cyclone are most favorable for the formation of tornadoes. The onward or progressive movement of the tornado is very small as compared with the speed of the winds that constitute the whirl.

ORIGIN OF THE WEST INDIAN HURRICANE.

Meteorologists have not yet arrived at a point where they can satisfactorily answer every question as to how, when, and where the West Indian hurricane originates, but enough is positively known to entitle their views for all practical purposes to the fullest confidence. The usual order of advance along any line of human learning is first the ideal or theoretical and then the real; so, in a review of efforts along this line we find a number of hypotheses being advanced only to give way under subsequent tests and fuller investigation. And yet each had its use and purpose and was a step in the right direction. As facilities for the study of these phenomena are multiplied and improved our present theories will eventually be freed from any erroneous elements that they may have. For the present, then, attention is invited to the following statements as to time, place, and manner of occurence of hurricanes. It is confidently believed that these statements rest upon the best authority and may be generally accepted as true.

(*a*) *As to time.*—The hurricane season—that is, the period during which hurricanes may occur in the West Indies, is generally recognized as extending from June to October, both months inclusive; the other months of the year are practically free from these visitations. The following table, quoted from Mr. Francis Watts, presents the relative frequency of West Indian hurricanes in the months constituting the hurricane season, viz:

June	1
July	4
August	10
September	8
October	7

Thus it appears that the month of August is the month of maximum activity in the formation of hurricanes, closely followed by the months of September and October. This suggests that a thorough study of the conditions obtaining during these months over the North Atlantic, the Caribbean Sea, and the Gulf of Mexico may furnish a partial explanation of questions relative to the origin of these storms. For instance, in August we find the great anticyclone of the Atlantic central between latitudes 30° and 35° north, and an area of low pressure is near the Cape Verde Islands. The doldrums of the Atlantic—an equatorial region marked by frequent calms—reach the northern limit of their journey during the months of August and September. Whether hurricanes shall occur in June or July seems to depend upon the extent to which the anticyclone of the Atlantic encroaches upon the Caribbean Sea. If the Caribbean Sea is only to a slight extent under the influence of the anticyclone, hurricanes may occur in those months; but if the anticyclone impinges upon the lower latitudes, hurricanes during these months are very improbable. It appears, then, that the movement of the anticyclone of the Atlantic is an important, not to say determining factor in the formation and movements of the West Indian hurricane.

(*b*) *As to place.*—All West Indian hurricanes do not originate in the same place. Of course they all form below the Tropic of Cancer, most probably between 5° and 15° north, but the longitude of the point of origin seems to be determined by certain influences which vary with the seasons. For example, the positions of the Atlantic anticyclone and that of the doldrums determine very largely whether the hurricane forms in the Caribbean Sea or near the Cape Verde Islands. Hence we find that if a hurricane occurs in June it usually forms in the western portion of the Caribbean Sea; the July hurricanes form in the middle or eastern portion of the Caribbean Sea, while the August hurricanes form anywhere in the Atlantic between the Lesser Antilles and the Cape Verde Islands. In other words, the point of origin of the West Indian hurricane appears to move eastward as the season advances, from the extreme western portion of the Caribbean Sea to the Cape Verde Islands. There is clearly an intimate connection between the eastward drift of the point of origin and the eastward drift of the Atlantic area of high pressure (anticyclone), as both occur at or about the same time. Another point worthy of note is that by the middle of August this region favorable to hurricane formation coincides with the doldrums on their northward journey, thus intensifying the forces at work in the formation of hurricanes. This eastward movement of the point of origin continues for about half the hurricane season; that is, from June to the middle of August. After that date there seems to be a return or westward drift along the same latitudes. Hence we find a marked similarity between the hurricanes occurring early in June and those of the latter part of October; those of the last of June and those of early October; those of July and those of September. This is particularly noticeable when we come to investigate the paths of the hurricanes for the different portions of the season. Therefore with the learned Viñes we conclude—

> * * * according to the position occupied by the equatorial zone of calms, by the Atlantic anticyclone, and consequently by the southern limit of the trade winds, respectively, the cyclone (hurricane) forms either more to the north or more to the south, and, above all, more to the east or west. The point of origin and formation of the hurricanes depend, therefore, on the more or less advanced season of the year.

(*c*) *As to manner of occurrence.*—The "convectional theory" of the origin of tropical storms, although it has not reached the point of direct demonstration, appears to be most reasonable. This theory may be stated as follows: A certain region within the Tropics marked by a uniform barometric pressure becomes rather warmer or moister than the surrounding neighborhood; the air over this region, because of its heat and moisture, becomes specifically lighter; in obedience to the principles of the convection of gases the lighter air has an upward tendency or buoyancy by reason of which a vertical circulation or overturning of the air occurs. The ascending warm moist air rises and overflows the colder surrounding air, producing an increased pressure at the surface of the ground in the region surrounding the heated region which contributes to the further inward flow toward the warm central area where the air pressure has been diminished by the overflow aloft. The inflowing currents at the surface and the outflowing currents above are connected by ascending currents over the heated region and descending currents on the outer boundary, thus forming a complete circuit. If these conditions were to occur on a very limited scale, or on a motionless body, the currents might flow directly inward below and outward above; but extending as these currents do over hundreds of miles and on the rotating earth they are deflected by centrifugal force to the right (in the Northern Hemisphere) thus giving them a curvilinear motion, so that the lower currents approach the center of the heated region in spirals. This is now the hurricane in its incipiency. Nor must it be thought that this work of preparation is the work of one day, but rather of many days. Day after day the air remains in ominous quietude over the watery surface of the ocean, becoming warmer and moister, gathering strength for its awful devastating career, while the watery vapor by diffusion and convection rises higher and higher until a large volume of air is almost saturated and very warm. Dense cumulus clouds are rapidly formed from which torrents of rain frequently fall. The air pressure continues to slowly decrease until at last the steadily increasing creep of the surface winds inward is followed by an overflow above; the movements are gentle at first, but increase until there is formed a violent whirl near the center.

The force of gravity and the deflective force due to the rotation of the earth are the two forces or factors in the formation of the whirl of winds, and to make as clear as possible the operation of these two forces, attention is invited to a study of figs. 1 and 2. Fig. 1 is intended to show especially the early stages in the development of the hurricane. At the center of this figure, let it be supposed, is the area of warm moist air, of gradually diminishing pressure, of decreasing cloudiness, and of heavy rainfall; in short, the future storm center. On the outside is the anticyclone of Galton or the pericyclonic ring of Ferrel, or the area of high pressure of the daily weather map. Now, as the pressure over this outer ring is greater than at the center, there must of necessity be a movement from the outer to the inner region just as certainly as water will flow from a higher to a lower level. If the earth were stationary this inward flow would take place along direct radial lines or the dotted lines in fig. 1. But according to Ferrel's great law a body moving along the surface of the earth in

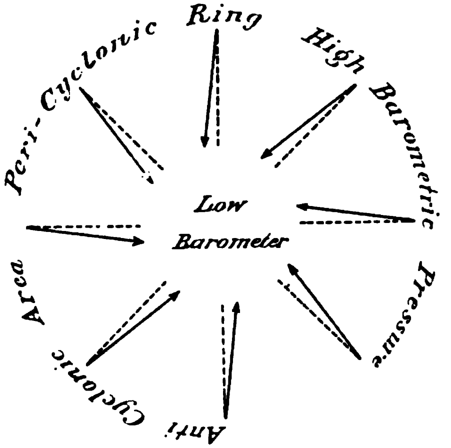

FIG. 1.

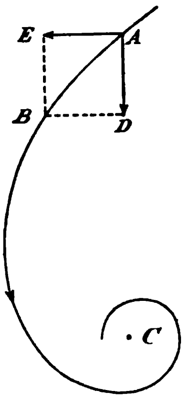

FIG. 2.

the Northern Hemisphere is deflected to the right by a pressure due to its rotation around the earth's axis as compared with the rotation of the points on the earth's surface over which it passes; hence we find the air moving along paths represented by the arrows in fig. 1. It appears at once from this figure that this deflective action will result in a gyration of the air involved in a storm about some central point. The deflecting pressure increases from the equator where it is zero, to the poles where it is a maximum; hence the statement that the region of formation of a cyclone must necessarily be so far north or south of the equator that this deflective force may become effective. It is scarcely necessary to point out that the greater the difference between the barometric pressure at the center and that in the pericyclonic ring, the more rapidly these inflowing currents must move.

Fig. 2 is a modification of fig. 56 in the Elementary Meteorology of Prof. William M. Davis, page 89, and is very helpful in this connection. In fig. 2 the resultant motion A B is resolved into its two component motions, represented by A D and A E. The former (A D) is the motion due to the gradient of pressure surrounding the storm center; it pushes the air inward toward the region of lowest pressure. The latter (A E) is due to the deflection attending any motion on the rotating earth. At a certain distance from the center (C) these two motions may possibly be nearly or quite equal in value, but as the center is approached the radial movement (A D) diminishes and the circumferential (A E) increases, so that the radius (C A) sweeps over equal areas in equal times in conformity to the law of conservation of areas. It is the circumferential motion that gives to the hurricane its destructive winds, as the radial movement alone would rarely if ever attain dangerous velocities. An air particle trying to move from A to C must, therefore, follow a spiral path around the center, rapidly increasing its velocity as the center is approached, so that eventually it whirls around the center without ever reaching it.

The following extract from page 198 of Davis's Elementary Meteorology is appropriate in this place.

> The origin of tropical cyclones thus appears to be well worked out. Being of convectional nature, they are not formed in the steadily moving trades, but only when the trades weaken in the loitering doldrums, where the lower air becomes excessively warm and moist. Being essentially whirling storms, they can not develop when the doldrums are close to the equator, where the inflowing currents are not required to unite in forming a systematic vortex, but only when convectional action begins at some distance north or south of the equator. The definite and rational association of these various conditions of storm growth gives warrant for much confidence in the convectional theory of the formation of tropical cyclones.

The correctness of this theory seems to be confirmed by the following facts, viz:

(1) All hurricanes originate during the season and in the region of high temperature.

(2) Copious condensation of water vapor attends their formation.

(3) An ascending current is indicated by the great cumulus cloud masses and the outflowing cirrus plumes and the drenching rains.

(4) Hurricanes behave in almost every particular just as one would expect from a study of convectional processes on a rotating body.

(5) Two seasons of violent storms occur in the Bay of Bengal; one when the sun moves northward and another when it returns southward.

(6) Hurricanes seem to originate only at places so far north or south of the equator that the earth's motion can impart a decided curvilinear motion to the inflowing currents of air.

(7) All features of the "eye of the storm" may be explained by this theory.

The full effect of the presence of moisture in the atmosphere during the formation and progress of tropical storms is perhaps not yet fully understood, but that it has a very powerful and important influence is certain. This is evident from the fact that these storms originate only in regions of very moist air, and are, as a rule, attended by torrential rains. It seems probable that the influence of the moisture is most potent after the vapor is condensed to cloud and rain, as, by the liberation of its latent heat, it then retards the cooling of the air and thereby prolongs the state of unstable equilibrium and so forces the currents to greater and greater heights. By catching all the sun's heat on the upper surface of a cloud the unstable equilibrium is intensfied. This also partially accounts for the enormous quantity of energy involved in the formation and movement of these storms. We quote again from Professor Davis, Elementary Meteorology, page 200:

> In order to realize the enormous amount of energy needed to develop a tropical cyclone we may quote a comparison that has been drawn between such a storm and a large ocean steamer. The air in a cyclone 100 miles in diameter and a mile high weighs as much as half a million 6,000-ton ships, and yet this enormous mass is set in rapid motion, averaging over 40 miles an hour, in the course of a few days and its motion may be continued for a week or more. Again the Cuban hurricane of October 5 to 7, 1844, is calculated on a very moderate estimate to have worked during the three days of its progress along our southern coast with an energy of at least 473,000,000 horsepower. The continued maintenance of so enormously powerful a disturbance calls for the rapid supply of a vast amount of energy, just as the active steaming of a large engine calls for a plentiful supply of coal under its boilers. In the case of a fully developed tropical cyclone it is believed that the energy is chiefly supplied from the latent heat of the heavy rainfall; and reasonable estimates of the amount of condensation within the storm disk show that this source of energy is ample in amount.

There have been those who held that hurricanes have an electrical origin; that electricity in some mysterious way produced the rotary movement of the atmosphere; but just how this was done no man could tell. This hypothesis has few if any advocates at the present time. The electrical displays which frequently attend the hurricane and give to it its awful appearance are to be regarded as unimportant concomitants, possibly even accidental rather than essential important characteristics.

It has been urged that hurricanes may be considered as whirls formed mechanically between north and south or east and west winds flowing past each other. But such whirls die away unless there be a continued supply of energy—such as is afforded by sunshine, by the latent heat evolved in forming cloud and rain and by the rotation of the earth.

(*d*) *Structure of the hurricane.*—So much, then, for the origin of the hurricane. Let us now see what we are to understand to be the structure of a perfectly formed hurricane. On this point attention is invited to the words of Father Viñes, as found in his memoir in Bulletin No. 11, United States Weather Bureau, and reprinted on page 7, United States Weather Bureau Bulletin No. 168, and again on pages 8 and 9, Bulletin H (W. B. No. 232), together with Professor Garriott's comments thereon. Father Viñes says:

> The aerial currents in a cyclone constitute a vast whirlwind around a central space of calm, of relatively small extent, called the "vortex" of the cyclone. It is an established fact that the direction of the rotary motion is always alike in the same hemisphere (northern or southern). In our own the cyclonic rotation is invariably from right to left, in the direction from east to north to west to south, or, as commonly expressed, in a contrary direction to that of the hands of a watch placed upon a horizontal plane, face upward. In the Southern Hemisphere the cyclonic rotation follows an opposite direction.
>
> In the West Indian cyclones the rotation and the cyclonic circulation take place in such a manner that the inferior currents, as a rule, converge more or less toward the vortex; at a certain altitude the currents follow a nearly circular course, and higher still their course is divergent. It is particularly to be noted that this divergence is all the greater as the currents occupy higher altitudes until a point is reached where the highest cirrus clouds seem to move in a completely divergent radial direction.

Professor Garriott says:

> The writer is prompted to question the accuracy of the conclusion of Father Viñes regarding a divergent radial direction of cyclonic currents in high altitudes. That the lower currents converge toward the vortex is an established fact; that the high upper currents have a divergent radial direction has not been established. Upper air cyclonic observations have been made only through an observance of cloud forms and cloud movements. These observations have shown that the different forms of cirrus clouds are carried by the controlling upper main current to the front, or in advance, of a cyclone; they have not shown that the clouds are projected back from the vortex. As a matter of fact the vortex acts as a chimney for the inflowing lower currents, and the moisture of these currents, which is condensed into cirrus clouds in high altitudes, is carried forward like smoke which emerges from the top of a chimney.

On page 12 of Bulletin H we find the following description by Dr. Enrique del Monte:

> *What a cyclone means.*—Before entering upon the description of the phases above referred to, we will say something about what may be called the structure of a cyclone.

What is a cyclone, aside from its origin?—The cyclone, and especially the tropical cyclone is characterized by a vast eddy, on an average 300 miles in diameter, of extraordinary violence in the gusts of wind (90 miles per hour, and sometimes more) and carrying, necessarily, with it a relative vacuum, which increases from the periphery to the center or vortex. This rarefaction of the air in so large an area implies a lack of equilibrium in the atmosphere, which, by the law of compensations, represents an excess of air in one or more isolated places surrounding the hurricane.

Therefore, if we suppose the barometer (which is only a delicate balance enabling us to weigh the atmosphere at any moment) to be situated in any place between the periphery and the center or vortex of the eddy, the nearer it is to the vortex the lower its column will be.

On the other hand, let us suppose the barometer situated beyond the body of the hurricane, but as near as it can be without the observer being able to perceive any sign of the storm, where, in compensation for the relative vacuum that makes an integral part of the neighboring hurricane, there will be, as stated above, an excess of air; consequently, the barometer will rise more or less, but higher than the normal, and in some places it reaches an extraordinary maximum.

The above-cited affirmation that the hurricane is characterized by a relative vacuum seems a paradox at first, since the testimony of our senses tends to show to us the contrary, in the unusual impetuousness of the winds, to such an extent that the existence of a hurricane is physically impossible without the wind having at least the velocity of a strong gale. This contradiction disappears if we have in mind what the wind means. In fact, the wind is only a mass of air that flows with more or less violence to the place at which, by any cause, a relative vacuum has been formed. From the gentle breeze, moving 2 miles an hour, to the furious gale, running 100 miles, all the wind velocities are subordinate to the above-cited general cause.

In order to explain to ourselves graphically the physical reason existing between the velocity of a gentle breeze and that of the furious gusts in a tropical hurricane, let us suppose an extent of ground 60 miles long, and let us suppose, too, five observers, provided with standard barometers and situated 12 miles apart, respectively. Now, let them take simultaneous observations at a preconcerted hour (10 o'clock a. m., for instance), and correct them for temperature and elevation. Everyday experience demonstrates that the larger the difference between the readings of the barometers at the stations, the greater is the velocity of the wind at that moment. These differences of readings in simultaneous observations are called in meteorological language barometrical gradients. The lines on the surface of the globe connecting places that present the same barometrical pressure at any moment are called isobarometric.

On page 531, Yearbook of the Department of Agriculture for 1898, Prof. F. H. Bigelow puts the matter thus:

By the laws of vortex motion the winds approach the center in spirals, the circular and centrifugal movements increasing every moment. At the core within the walls of the columnar vortex the air circulates about the calm central part, gradually rising to the cloud stratum, just above the inflowing disk. Here the air flows out suddenly on all sides, the circular motion decreasing, the air cooling by expansion, causing a great, thin sheet of rain 200 to 300 miles from the center. At this distance the vortex sheet turns up suddenly (not down, as usually stated) and discharges the expended matter into the high upper currents of the atmosphere. The feeding wind lines are more nearly parallel to the ground than the upper discharge lines, but they all form a columnar vortex of unusual configuration. There is probably no feature of nature more interesting to study than a hurricane, though the feelings of the observer may sometimes be diverted by thoughts of personal safety.

(*e*) *Movements of the hurricane.*—Rotary storms have two distinct movements, and a failure to understand each of these and its peculiarities is responsible for much of the confusion so painfully apparent in public thought, whereas a clear comprehension of these two movements affords at once both a key to much valuable information on this subject and a basis upon which to rest many reliable prognostics, as well as precautionary measures for the protection of life and property. Anyone desiring to be informed on this point will do well to take pencil and paper and by a careful study of actual drawings will soon come to a clear understanding of the changes which necessarily result from a combination of a gyratory and a translatory motion of the winds at any particular place within the disturbed area during the passage of the storm.

(1) *Gyration.*—The first motion we will notice is that about the center of the storm. There is, at the very center of the storm, a region of calm, sometimes called the "eye of the storm," which averages about one-thirtieth of the diameter of the entire hurricane. The motion about this central region is, in the northern hemisphere, invariably from the right to the left; that is, we have east winds on the north, west winds on the south, south winds on the east, etc. The path of a particle of air is very nearly circular when it is close to the center but departs more and more from the circle as its distance from the center increases. This is because the winds approach the center in spirals, one of the results of which is an increase in the angular motions as the center is approached as well as an increase in the velocity and violence of the winds. It is this circular motion that renders the central area of the hurricane so dreadfully destructive, for which reason this motion should be carefully studied as many of the precautionary measures must be based upon its peculiarities. Then, again, as the inflowing winds ascend about the central area they become still more nearly circular at certain elevations and at still greater heights become more or less divergent and finally become completely so, flowing outward in radial lines, as shown by the cirrus plumes; but the outflow is often not perceptible except in the direction toward which the whole whirl is moving. These features of the gyratory motion at different elevations afford a basis for the most reliable premonitions of the formation and progress of the hurricane, as will hereafter appear.

(2) *Progression.*—In addition to the circular vortex motion just discussed the hurricane has a translatory movement; the center describes a path resembling a parabola whose opening between the branches is directed toward the east. The rate at which the center moves along this path varies not only in different hurricanes but even in the same hurricane at the different stages of its progress. The path of the hurricane may be considered as made up of three divisions, viz, the

first branch, the recurve, and the second branch. It is highly probable that while the hurricane is passing along the first branch the rate of movement is slightly on the increase, while in the vicinity of the recurve the rate is retarded, especially at the recurve of narrow parabolas where the vortex may remain practically stationary for a time.

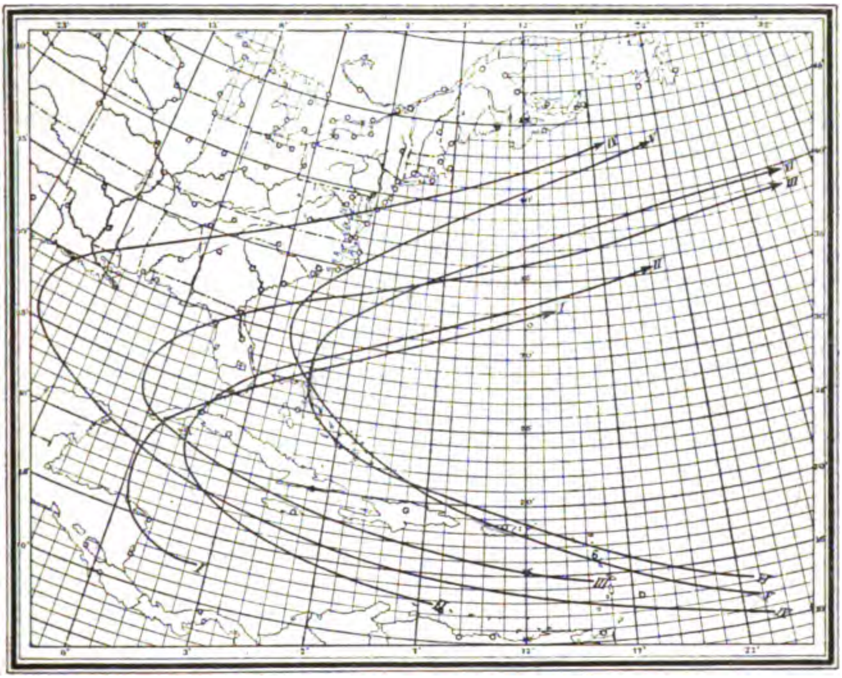

FIG. 3.

In the second branch of the track this translatory motion increases steadily and may attain 30 or 40 miles per hour. Perhaps 18 miles per hour would be a fair average for the hurricane along the first branch of its path. This path changes in form, being more or less open, at the different periods of the hurricane season, as may be readily seen from an inspection of fig. 3. The paths of hurricanes shown on this chart represent respectively the averages of certain typical groups of paths. It is not to be supposed that hurricanes only occur along these paths; on the contrary, they may occur anywhere within this hurricane region, but when they do occur, they are likely to run in paths parallel to the types here shown for the different seasons. This chart is an effort to present graphically Father Viñes's "Law of the normal direction of the tracks at the different dates and latitudes," which law as originally tabulated is also reproduced in Table I. The form of the track for the different months and decades specified remains the same, but its geographical position depends upon the place of origin or the point at which the hurricane enters the region of the West Indies. In other words, should a hurricane form or enter the West Indian waters at the points arbitrarily assumed on the diagram above referred to, then it would most likely follow the track laid down. These laws are of value, therefore, only after the latitude and longitude of the vortex of the hurricane have been ascertained at any particular time, as it is then possible to locate the probable path of the entire storm if the proper decade or month is taken into account. It is plainly evident that the path of the hurricane soon carries the hurricane beyond the tropics into the temperate zone where it assumes more and more the characteristics of a cyclone by spreading out over a larger area and thus losing its violent nature as it journeys northeastward; hence it may be said that the hurricane bears within itself the seeds of its own destruction.

Referring to figure 3, it will be seen that Track I is intended to represent the average path of a hurricane occurring during the first decade of June or the third decade of October; Track II, a hurricane occurring during the second decade of June or October; Track III, a hurricane occurring during the third decade of June or the first decade of October; Track IV, a hurricane occurring in July; Track V, a hurricane occurring in August, and Track VI, a hurricane occurring in September.

TABLE I.—*Normal directions of the tracks at different dates in different latitudes, as given by Viñes.*

Dates.	Directions.						
	W.		WNW.		NW.		NNW.
	°	°	°	°	°	°	°
August	10	15	15–20	20–25	25–27	....	28
July and September	10	15	15–24	....	25	....	26
June 21–30 and October 1–10	10	15	15–20	....	21	....	22
June 11–20 and October 11–20	10	....	12–14	....	15–16	17	18–19
June 1–10 and October 21–31	10	12	13	....	13–14	....	15

Dates.	Directions.						
	N.		NNE.		NE.		ENE.
	°	°	°	°	°	°	°
August	29–33	....	34	....	35–40	....	....
July and September	27–29	....	30	....	32	33–35	35–40
June 21–30 and October 1–10	23–26	....	27	28	29	30	31–40
June 11–20 and October 11–20	20–23	....	24	25	26–30	....	....
June 1–10 and October 21–31	16–20	....	22	23	24–30	....	....

For a full discussion of this law see "Cyclonic circulation and the translatory movement of West Indian hurricanes," page 19, et seq.

CHAPTER II.

PREMONITORY SIGNS OF THE EXISTENCE AND MOVEMENT OF A HURRICANE.

Nature mercifully forewarns the careful observer of the approach of dangerous atmospheric conditions and disturbances by signs more or less definite and reliable. When taken in combination, especially over large areas, these signs are unmistakable, and are more evident at the very places over which the storm's center is about to pass. These signs afford no basis for "long-range forecasts;" we can not by them foretell the formation of these storms weeks and months in advance. About all we can hope to do is to ascertain the existence of the disturbance at a distance and predict its probable path.

Bearing in mind, then, the physical structure of the hurricane, as above set forth, we are prepared for an intelligent consideration of attendant phenomena, some of which must always be present, and are well-recognized premonitions of the existence and movement of the West Indian hurricane. It is not to be understood that a hurricane follows upon the appearance of each of the signs mentioned below, nor is a hurricane necessarily heralded by all the indications given, but the appearance of one or more of these signs during the hurricane season should inspire alertness on the part of the observer in proportion as they accumulate and become more and more unmistakable as the danger draws nigh. These signs are such as the observer recognizes by means of the barometer, the sea, the air currents, the sky, the atmosphere, and the surface winds. The nature and significance of these warnings are easily understood from the definite lines upon which the hurricane is formed.

1. *The barometer.*—This instrument, if a good one, and more especially the self-recording barometer or barograph, is a most trustworthy friend during the hurricane season; in fact it is indispensable in the study of the hurricane if one desires to possess all possible foreknowledge. It often gives the observer the first indication of distant cyclonic formation; it keeps him reliably posted as to the tempest's progress, and brings the first ray of hope that the worst is over. The first intimation to be looked for, and to be detected only by means of the barometer, is an increase in the atmospheric pressure, as shown by an abnormal

rise of the barometer. This increase may be due to the flow of air toward the distant low pressure or it may mark the pericyclonic ring of high pressure about the vortex; it is often the earliest possible tidings of the hurricane. This rise usually occurs when the storm center is far distant—possibly as much as 500 miles—from the observer. It is followed by a fluctuating barometer, due to irregular and conflicting air currents. After this the barometer begins a gradual decline, the fall becoming more rapid as the storm approaches. The passing of the center is promptly shown by a rising barometer, the rise being sometimes as rapid as the fall during the approach of the storm.

2. *The sea.*—The sea may also be relied upon to give very early tidings of the existence of a cyclonic formation, by the appearance of long rolling swells, apparently without cause, which are rapidly propagated from the storm's center in all directions. These are sure signs of the existence, but not necessarily of the approach, of a storm; the storm may be approaching or passing, the swells are the same. The sea often has a glassy appearance some days in advance of the storm, and is very clear. Then again it has "the appearance of a boiling pot, the waves running in all directions, with their caps falling back just as though a change of wind was coming." These waves and swells and rollers are greatly modified by islands and shoal water, so that each locality must be studied especially. The sea becomes more violently agitated as the hurricane comes on, and at its worst is truly awful.

3. *The air currents, or cloud movement.*—The air currents, as shown by cloud movement, especially the upper currents, afford valuable data for locating the disturbance and for determining something of the hurricane's probable path. As the currents at the cirrus level are believed to flow outward from the vortex in radial lines, a study of the cirrus clouds becomes at once highly important. But cirrus clouds are not all alike, nor do they all have the same significance. Hence it becomes necessary to classify, and in this, as in many other instances, we can at present do no better than to follow Dr. Viñes. He selects two extreme types: The first or typical cirrus is a snow-white, featherlike cloud, and on account of its fibrous structure is often called "mare's tails." The stem or shaft of the "feather" is very dense fibrous. If there be two or more of these cirrus plumes all of them converge to a point on the horizon, thus locating the center of the disturbance. The second type is of a filiform structure, belt shape, and of great extension. These clouds may form belts or zones across the sky and resemble more or less the tail of a comet, so attenuated or gauze-like are they in structure. The first type of cirrus belongs to a hurricane of great violence though of small diameter. It usually appears when the storm is between 300 and 400 miles distant

from the observer. The second type pertains to hurricanes of large diameter but of moderate violence, and usually appears when the storm is yet distant 700 or 800 miles.

Between these two types there is an almost endless variety of cirrus forms, but the character of the approaching storm may be fairly estimated by the nature of the precursory cirri, remembering that the more nearly they conform to the first type the more perfect the cyclonic formation; and the greater the departure from the first and the more like the second, the less perfect though more extensive the cyclonic formation.

These highest cirrus bands or plumes therefore tell at once the direction in which the storm center is likely to move, and the observer who finds them streaming toward or over himself may know that the center is coming toward him.

On the other hand, the lower clouds and winds tell us only the location of the center at any moment, and we must observe these for several hours in order to determine how they are changing before we can conclude anything as to the movement of the center.

The lower air currents, as shown by the movement of the lowest cumulus clouds, circulate so nearly in a circle that the storm center may be assumed to be in a direction at right angles to the cloud motion. Above these cumuli the currents make angles with the bearing of the vortex that are sharper as the cloud level is higher. Fig. 4 presents these relations as they are believed to exist in a well-developed hurricane of considerable intensity. The center of the storm is shown in the lower right-hand corner of that figure; the air currents around that center generally show some such arrangement as indicated by the arrows; the highest cirrus clouds move directly outward from the center on all sides, but by far most decidedly in one direction, namely, that toward which the storm is moving, as, for example, west-northwest in the diagram; the cirro-cumulus clouds move in paths that make an angle of about 22½°, or two points of the mariner's compass, with the radius drawn to the vortex of the hurricane; the motion of the cirro-stratus clouds makes a still greater angle, say 45°; that of the alto-cumulus clouds makes an angle of about 67½°, or six points, and that of the lower cumulus clouds an angle of 90°, or eight points, while the surface winds make a still greater angle, and therefore flow inward. All hurricanes are not perfect in their organization, consequently the observer must be prepared for and expect modifications in the above relations. The radial movement of the cirrus clouds is so frequently to be relied on that preference should be given to these clouds in determining the location or bearing of the storm center and its probable progress, especially while it is yet far distant.

If there be no cirrus clouds then quite possibly the storm is not advancing toward the observer, but will pass by him to the right or the left. In this case its movement may be determined by studying the motion of any lower cloud that is visible, or if need be, that of the wind. To this end the observer must carefully determine the direction of motion of wind or cloud, from time to time, several hours apart. If this motion veers, namely, changes in the order N., NE., E., SE., S., SW., W., NW., N., then the storm center as it advances will deviate to the right of the observer's station. If the wind backs, namely, changes in the order N., NW., W., SW., S., SE., E., NE., N., then the center will deviate to the left of the station. If no veering or backing is observed, then the storm center must be moving very nearly toward the observer.

The exact direction of movement of the cloud or wind is best observed by the help of a nephoscope, which is essentially a horizontal mirror upon which one may lay a short piece of stick or wire and adjust this until it exactly covers the reflection of any cloud that is seen moving across the mirror.

(NOTE.—The latest confirmation of the general rule that high cirrus clouds flow from the hurricane center outward, but principally in that direction toward which the center is moving, comes from Mr. John T. Quin, editor of the St. Croix Avis, published at Christianstad, in the island of St. Croix. In that journal for September 14, 1901, speaking of the hurricane of Wednesday, September 11, he says: "It may interest amateur observers to mention that the first hint of the recent storm was given by the sky. A careful observation of some high clouds at 5 p. m. on Tuesday, September 10, showed that they were coming from east-southeast. The editor mentioned this fact and its probable significance to a friend at that time, and the Weather Bureau's telegram arrived a couple of hours afterwards. Yesterday, the 13th, the storm having passed us, the high clouds were observed moving from about west-northwest—that is to say, they were still coming from the cyclone center."—C. A.)

In fig. 4 we have shown in a general way the incurving of the wind and clouds near the center of the West Indian hurricane, but for the convenience of those who prefer a more direct statement we give the following table, showing in the first column the bearing of the hurricane center from the observer; in the second column the approximate direction of movement of the lower clouds, viz. either the cumulus or the scud; in the third column the direction of the wind when the location is quite free from obstacles that may change the direction. At various distances from the center these wind directions vary somewhat, so that those given in this column are not those invariably experienced, but a range of two points must be looked for. Thus, if the center is east of the observer he may confidently expect the lower clouds to be moving very nearly from the north, but the lowest surface winds may be anywhere between north-northeast and west-northwest. This consideration shows the importance of observing the cloud directions with great care. In order to do this with considerable ease the landsman has only to make use of a small mirror or a bowl of water in which he can see the reflection of the clouds. He is to hold the eye steadily in one position while the reflection of the cloud is seen to pass across the mirror or water. Lay a straight edge across representing the path of the clouds, and then determine the angle which the straight line makes with the meridian. One ought really to have a very correct idea of the true north and south line, and if a magnetic compass is used one should make allowance for its deviation from the true north, although fortunately this is quite small in Porto Rico.

General relations of winds to the storm center.

The storm center bears—	The low clouds move from—	The winds blow from—
ESE.	NNE.	N.
E.	N.	NNW.
ENE.	NNW.	NW.
NE.	NW.	WNW.
NNE.	WNW.	W.
N.	W.	WSW.
NNW.	WSW.	SW.
NW.	SW.	SSW.
WNW.	SSW.	S.
W.	S.	SSE.
WSW.	SSE.	SE.
SW.	SE.	ESE.
SSW.	ESE.	E.
S.	E.	ENE.
SSE.	ENE.	NE.
SE.	NE.	NNE.
ESE.	NNE.	N.

4. *The sky.*—The passage of the pericyclonic ring surrounding a hurricane is marked by deep blue and nearly cloudless skies, followed by a few days of sudden and decided changes in the appearance of the sky; quick changes from clear to cloudy and from cloudy to clear; small fragmentary clouds may often be seen passing across the sun's disc; at sunset the sun appears to be shorn of his beams and shines with a pale sickly light, and the sunrise and sunset colors are unusually brilliant. Solar and lunar halos are frequently to be seen.

5. *The atmosphere.*—The atmosphere some days in advance of the storm possesses comparatively low relative humidity and dew-point, then follows a period of great fluctuations in the humidity and dew-point. At times the air becomes very warm and sultry, as if from a furnace, often presenting a hazy or milky appearance.

6. *The surface winds.*—Some days preceding the storm the trade winds become unsteady, the light breezes dying away and then reviving again. Finally, if the rise in the barometor has occurred because of the passage of the pericyclonic ring, then the air settles down to a calm that is followed by a gradually increasing wind which blows in

gusts at first with occasional calms. "In the air there may be often heard queer sounds like the cracking of whips or far-away pistol shots. Besides this a deep rumbling noise—a sort of growling—may be heard."

7. *The weather.*—Fine and rather cool weather may be looked for during the prevalence of increased air pressure, but as soon as the barometer begins its steady fall, the sky begins to assume an angry, threatening aspect, and ere long has a peculiar indescribable appearance, which assures the observer of an approaching danger. This "something" about the weather must be experienced to be understood, but once seen it is readily recognized; it appeals directly to the senses, and may be that which impels the sea birds to make for the land, as if by instinct, to protect themselves from the fury of the coming gale.

In this connection we quote what a few eminent writers have said relative to premonitory signs of the approaching hurricane, and thus make this discussion as complete as possible. First we offer a few words from Professor Bigelow:

> The physical features of hurricanes are well understood. The approach of a hurricane is usually indicated by a long swell on the ocean, propagated to great distances and forewarning the observer by two or three days. A faint rise in the barometer occurs before the gradual fall, which becomes very pronounced at the center. Fine wisps of cirrus clouds are first seen, which surround the center to a distance of 200 miles. The air is calm and sultry, but this is gradually supplanted by a gentle breeze, and later the wind increases to a gale, the clouds become matted, the sea rough, the rain falls, and the winds are gusty and dangerous as the vortex comes on. Here is the indescribable tempest, dealing destruction, impressing the imagination with its wild exhibition of the forces of nature, the flashes of lightning, the torrents of rain, the cool air, all the elements in an uproar, which indicate the close approach of the center. In the midst of this turmoil there is a sudden pause, the winds almost cease, the sky clears, the waves, however, rage in great turbulence. This is the eye of the storm, the core of the vortex, and it is perhaps 20 miles in diameter, or one-thirtieth of the whole hurricane. The respite is brief and is soon followed by the abrupt renewal of the violent wind and rain, but now coming from the opposite direction, and the storm passes off with the several features following each other in the reverse order.—Yearbook, Department of Agriculture, 1898, page 531.

We now quote Mr. Francis Watts, F. I. C., F. C. S., who puts the matter thus:

> Much is heard about the prediction of hurricanes. It should be clearly understood what is meant by such an expression. The prediction of a hurricane weeks or months before its formation is clearly a thing impossible in the present state of our knowledge. All that can be done is to ascertain the existence and predict the probable course of a cyclone already existing. We have seen that a cyclone is built on certain definite lines and certain phenomena invariably attend its approach.
>
> The following premonitory indications are largely taken from the United States Pilot Chart for August, 1891. Before a hurricane the barometer is somewhat higher than usual, with cool, very clear, pleasant weather; there is a low long swell from the direction of the distant storm; the sky is covered with a quantity of light feathery cirrus clouds (Mare's tails), radiating from a point on the horizon, where a whitish arc indicates the bearing of the center. If the cirrus plumes are faint and opalescent in tint,

fading gradually behind a slowly thickening haze or veil, the approaching storm is an old one of large area; if they are snowy white, projected against a clear blue sky, it is a young cyclone of small area, but great intensity. Great activity of movement of the upper clouds while the storm is still distant indicates that the hurricane is of great violence.

As the storm approaches, the following unmistakable signs display themselves: The barometer falls rapidly; halos are seen about the sun and moon; the ocean swell increases, the weather becomes hot, moist, and oppressive with light variable winds; deep red and violet tints appear at dawn and sunset, which tints assume a coppery glare of ominous aspect; a heavy mountainous cloud bank on the distant horizon indicates the position of the approaching storm; the barometer falls more rapidly, and finally, if the observations are made on or near the storm track in the West Indies, the wind begins to blow in a direction between the northeast and northwest soon rising to hurricane force, increasing till the central calm passes over with violence from the south to southeast.—Occasional Bulletin, No. 10, Botanic Station, Barbados, p. 7.

The following extracts from a memoir by Dr. Enrique del Monte of Havana, are reprinted from Bulletin H, West Indian Hurricanes, by Prof. E. B. Garriott, pages 13–18:

First phase of the hurricane: The anticyclone.—Hence, we have already the first phase of the hurricane; and when its vortex is on an average 1,500 miles off. This phase is called the anticyclone. As its name indicates, it is the reverse of the cyclone. In fact, the meteorological elements follow in it a course different from the normal, and quite different, too, from that in the dominion of the hurricane.

Its distinctive features are the following:

1. An anomalous rise in the barometer. It reaches sometimes an exaggerated maximum.
2. Fine and rather cold weather. The temperature goes, on an average, 14° F. below the normal.
3. Cloudless sky, and of a decidedly indigo blue. Consequently in this kind of weather the dew-point and relative humidity are always far below the normal.
4. Persistency of the anticyclonic winds. That is to say, the daily shiftings from the land to the sea breezes, and vice versa, disappear entirely, or at least are greatly disturbed.
5. Different order in the circumgyration of the atmospheric currents from those in the hurricane. In the anticyclone the gradation is from right to left, beginning from the lowest current.

Summing up we will say, that all the anticyclones that may appear to the observer, presenting the features above referred to, always indicate a priori the existence of an atmospheric disturbance. In the island of Cuba, when they appear in the months of cyclonic activity, they must be always carefully observed and studied, as their subsequent positions may furnish the observer with valuable information regarding the hurricane. On the other hand, when their appearance takes place in the months of no cyclonic activity, they pertain to hurricanes of high latitudes, although in some instances, as we shall see in the next section, they may offer some danger to navigation on the northern Cuban coasts.

Second phase of the hurricane—Mean zones or intermediate spaces between the anticyclone and the cyclone.—Soon after the influence of the anticyclone has passed by, and while on the other hand the approaching hurricane is still far enough away to prevent its detection, the following phenomena are generally noticed:

1. The barometer begins to fall slowly. Irregularities and fluctuations in its column are always noticed, owing to the antagonizing influences exerted on it.

2. The appearance of the sky is highly changeable, passing sometimes in a few minutes from entirely clear to cloudy and vice versa.

3. Consequently the temperature and moisture of the air are also very fluctuating.

4. The wind directions in the different atmospheric strata are singularly unstable. We have frequently observed the passing of those currents, in a very short time, from anticyclonic to cyclonic and vice versa.

All the above weather features are always more or less perceptible under approaching cyclonic conditions and after the gradual recession of the anticyclone. The brightness of this phase obviously depends on the power exerted by both the anticyclonic and cyclonic systems as well as on their relative position to the observer.

Third phase of the hurricane—Changes and phenomena to be observed in the upper strata of air.—This phase begins when the anticyclone in its progressive motion is so far away as to be imperceptible to the observer, while the hurricane is gradually approaching him.

Alteration of the light in the upper strata of air—Reddish and ruby skies.—This phenomenon is always noticeable when the outermost part of the hurricane begins to invade the place of observation. The unsettled weather, described in the last section, gradually disappears and the barometer falls now steadily but rather slowly. By this time the transparency and blueness of the sky, characteristic of the past anticyclonic weather, is succeeded by an opaqueness or veil called cirrhose veil, so extremely subtle in the beginning as to render it almost imperceptible. Notwithstanding its subtlety this veil exerts a very great absorptive power on the solar rays, its principal feature being the almost entire absorption of all the prismatic colors, except red. The dispersive and absorptive powers are singularly remarkable when the solar rays are compelled to pass through a great portion of the atmosphere. Consequent upon this the sun's rising and setting are attended by an anomalous reddish coloration in the sky ending or beginning when the sun's altitude is, on an average, 15°; the coloration increases as the altitude decreases.

Precursory cirri and their magnificence—Invaluable data to be derived from their appearance.—Just here the observer is confronted with the most splendid phenomenon to be observed in tropical meteorology.

Soon after the reddish coloration is noticed the tribe of cirri makes its appearance. These clouds are oftentimes called "Pele's Hair," "Mare's Tails," etc., on account of their fibrous or filiform structure. As is well known, they resemble in their form a feather or plume of highly variable dimensions.

The appearance of these clouds whenever pertaining to tropical hurricanes, shows an organization seldom noticed, if not unknown, in those attending high-latitude storms. In fact, during a long stay in New York, N. Y., we have had ample opportunity to watch a good many specimens of cirri in connection with storms of very different energies, but have utterly failed in detecting any similitude with those frequently observed in the West India hurricanes.

The shape of the typical tropical cirrus is that of a most perfect and remarkably beautiful feather or plume, snow white, in which the shaft or stem is of a fibrous structure, great density, and averaging 80° in angular length. The barbs or vanes are equal and closely distributed on both sides of the stem, being of filiform structure, divergent, and of marked outward curvature.

It is also noticeable in connection with these clouds that when there are two or more, as is usually the case, all of them agree in their directions, converging to a given point on the horizon. This point is called the focus; i. e., the perspective vanishing point.

Whenever these cirri are carefully observed a great activity or instability is always detected as taking place in their masses; their lengths are frequently seen increasing or diminishing in a short space of time.

In spite of this instability the cirrus is never deflected from its primitive direction.

Solar and lunar halos, parhelia and paraselene, threatening skies.—Shortly after the appearance of the precursory cirri it is always noticeable that the subtle opaqueness or veil has gradually acquired density and now resembles a light curtain of a milky appearance. During this phase the delicate filaments of the cirri are almost imperceptible, owing to the interposition of the veil.

Solar and lunar halos are phenomena always attending this kind of weather. The parhelia and paraselene are seldom noticed. At the beginning the halos are of a weak appearance, but later, and when the veil is still denser, they usually display extraordinary brilliancy, which afterwards gradually declines as the veil is changing to a dark cinereous color.

The reddish colorations attending the sun's rising and setting are now of a most indescribable and threatening appearance, resembling the resplendence of a bright polar aurora. The ruby color gradually turns into crimson as the sun approaches the horizon, and shortly after sunset the whole sky has the appearance of an enormous conflagration.

Cirrhose arch—Its appearance.—While the cirrhose veil is increasing in density, as we have seen in the last section, it is always noticeable that at a given point in the horizon the condensation of the veil is greater. There the veil has the appearance of a segment of a circle at first tangent to the horizon, but gradually rising to a maximum of perhaps 10° above. This arch is generally called the cirrhose arch. Its color at the beginning—that is to say, during the phase of which we are now speaking—is the same as that of the veil covering the whole hemisphere, only that the accumulation of vapors being greater where the arch appears, its reflecting power is necessarily greater; so that in spite of the identity of colors between the cirrhose veil and the arch the latter seems perfectly detached, a similar phenomenon to that always noticed in the tail of a comet, where the tail is brighter near the borders than along the middle, in spite of the uniformity in its color.

The point in the horizon at which this arch is formed always coincides with the vanishing point of the observed cirri, and therefore with the bearing of the vortex from the observer. In fact, the arch is but the visible upper part of the approaching hurricane.

Seamen navigating the tropical seas in the hurricane season must carefully observe whether, after the appearance of the precursory cirri, the cirrhose arch is formed, attended by halos and reddish colorations, with falling barometer. In this case there is no time to be lost. Let them consult without delay the charts of normal tracks for the different months of cyclonic activity, and if they find themselves to be in a dangerous zone adopt immediately the measures they may deem necessary.

Bar of the hurricane; its appearance—Data to be derived from its observation.—The cirrhose arch, described, gradually changes as the hurricane is approaching. At the beginning its color is of a whitish-milky appearance, but now its color is rather dark and opaque, soon to be turned into black. After this change in its appearance the arch is called the bar of the hurricane.

The bar has the appearance of an arch whose altitude above the horizon is generally from 10° to 15°. It is formed in its upper section by cumulo-stratus, and in the lower one by a nimbus of great size and black color. The base of the bar is always concealed below the horizon, so that a want of continuity between the bar and the horizon is never detected.

Showers and squalls; their phenomena.—Shortly after the bar is formed in the horizon the nimbus of the hurricane begins to overrun the skies with inexhaustible succession and high speed. Showers of short duration begin, and the wind velocity increases from that moment. The barometer that has been slowly falling since the beginning of the second phase now drops abruptly.

It may be well to notice here that in every perfect hurricane of great or relative moderate intensity the rain at the beginning is of a showery nature, attended by squalls from 55 to 65 miles an hour, while the mean velocity of the wind is from 35 to 40 miles. On the contrary, as the vortex approaches the rain is always continuous, although highly irregular, the showers succeeding each other at shorter intervals and always attended by furious gusts that apparently attain 100, 110, and sometimes 120 miles an hour.

As is well known, the energy of every tropical hurricane is always in close relation with the frequency and fury of the attending showers. The hurricanes are fed and their activity maintained unabated by the characteristic showers which accompany them, by reason of the fact that the rapid upward convection contributes largely to a more and more severe precipitation.

Of all the premonitory signs of an approaching hurricane, the following, at least, may be regarded, so far as the West Indies are concerned, as invariable, not to say essential: First, a continuous fall of the barometer; second, a strong wind from some northerly point (northeast, north, or northwest), blowing with an increasing force; and third, a rough, intumescent sea. These are practically invariable, and if one or more be wanting there is little cause for alarm.

While searching through an old work entitled Atlas Geographus, published in London in 1717, the following interesting reference to hurricanes was found in Volume V, page 520, and is here reproduced in conclusion of this chapter:

> It (St. Kitts) was formerly much troubled with earthquakes, which are in a great measure ceased since the eruption of a sulphurous mountain in the island; but hurricanes are still frequent here, and the European inhabitants used to send about June to the natives of Dominica and St. Vincent, who constantly gave them notice of the hurricane about 10 or 12 days before it came. In Lowther's Philosophical Transactions, Vol. II, page 105, the curious will find certain prognosticks of the approach of a hurricane, as they were discovered by an Indian to Capt. Langford. They come generally in August, on the full change or quarter of the moon, and never before the 25th of July, nor after the 8th of September. Among other signs of their approach, the skies are very turbulent, the sun redder than usual, and the hills clear of clouds or fogs. In the hollows of the earth or wells there is a great noise; the stars at night look very big, with burs about them, the northwest sky very black, and the sea smells stronger than usual. Sometimes on the day when it comes the wind blows very hard west out of its usual course.

CHAPTER III.

THE APPROACH AND PASSAGE OF A WEST INDIAN HURRICANE—SUGGESTIONS RELATIVE TO PREPARATIONS FOR SUCH STORMS.

During the hurricane season due diligence should be exercised by keeping a close watch on the state of the weather in order that the first signs or indications of the formation or approach of a hurricane may be detected. So soon, then, as the existence of the hurricane is manifest the next serious consideration is the determination, so far as practicable, of the observer's position with reference to the center and bearing of the storm, because this will afford a basis for subsequent action. The safest conclusion on this point will be reached from a careful study of weather telegrams from surrounding points; but in the absence of these we must study cloud movement and the surface winds, in connection with the law governing the paths described by the centers of hurricanes at the different seasons and latitudes, as explained in a preceding chapter. This law should be kept in mind, as the suggestions here made are subject thereto. In this connection it is also advisable to study Fig. 3 and review what is said in the preceding chapter relative to the relation between the bearing of the vortex and the cloud movement.

If high cirrus clouds are present and visible they will indicate the bearing of the center from the observer; if there are no cirrus clouds, or if the sky is overcast by lower clouds, it is then best, perhaps, to study the low cumuli, as these move very nearly at right angles to the bearing of the vortex. Hence, if the observer stands facing in the direction from which the low cumulus clouds are coming, then turns to his right through an angle of 90°, he will be looking in the direction of the center. If, however, only the surface wind is observable, then he must turn to his right through an angle greater than a right angle, since the surface winds make with the direction of the storm center an obtuse angle, especially at some distance from the center. A single observation of the wind does not tell anything with regard to the path of progress of the storm. Having now ascertained as best we can the location of the storm center, the observer next considers whether the center will pass over him to the north or to the south. Knowing this, then, the directions from which the wind will blow during the approach and passage of the storm will become known and precautionary measures may be taken accordingly. Unfortunately, the best that can be done in the solution of this problem is only an approximation. In fig. 4 five cases of such hurricane paths as can occur in the West Indies are indicated. The position of the observer may be at either of the figs. 1, 2, 3, 4 or 5—i. e., west or north of the central calm region. If the storm center is coming directly toward him he will know this by the direction of motion of the clouds in the sky above him. The motions of the clouds are shown by small arrows.

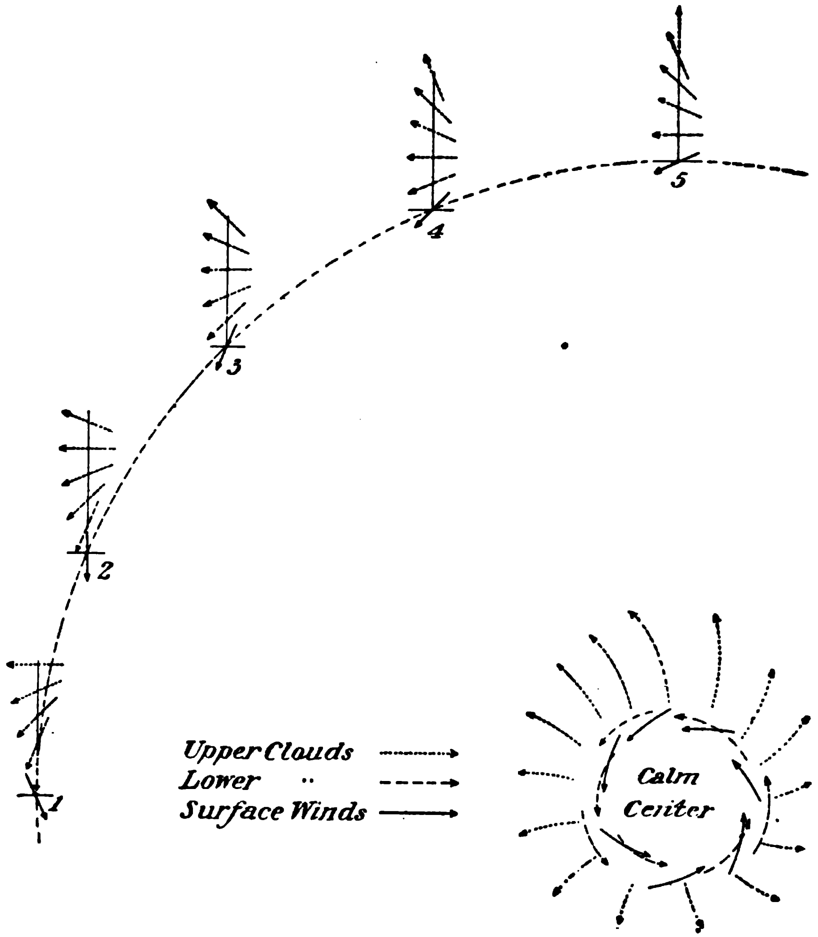

FIG. 4.

The observer located at the points 1, 2, 3, 4, 5, in fig. 4, and having a storm approaching him from the calm center C, will usually observe that the successive layers of clouds above him are moving in different directions, as indicated for each location in the following table, and also shown by the arrows placed vertically above each location in fig. 4. The kinds of clouds and their respective movements vary quite regularly as we ascend above each locality.

Table showing movements of successive layers of clouds.

Stratum of cloud or mist.	Inclination of movement to radius.	Direction of movement of winds and clouds (true, not magnetic) as observed at different stations.				
		1.	2.	3.	4.	5.
(1*a*) Snow-white cirrus, feathery plume, fibrous mares' tails, flowing from the center, or converging to the center, appearing when the center of a small storm is 300 miles distant	° 0.0	E.	ESE.	SE.	SSE.	S.
(1*b*) Cirrus of filiform structure, long belts or zones, gauzy structure like comets' tails, appearing when the center of large storm is 700 miles distant	0.0	E.	ESE.	SE.	SSE.	S.
(2) Cirro-cumuli	22.5	ENE.	E.	ESE.	SE.	SSE.
(3) Cumulo-stratus, or dense cirrus veil	45.0	NE.	ENE.	E.	ESE.	SE.
(4) Alto-cumulus	67.5	NNE.	NE.	ENE.	E.	ESE.
(5) Cumulus	90.0	N.	NNE.	NE.	ENE.	E.
(6) Wind	112.5	NNW.	N.	NNE.	NE.	ENE.

Case 1: It most frequently happens in the Windward and Leeward islands that the center of the storm (C) moves nearly westward toward the observer at O_1 and in the direction of the higher cirrus clouds, as shown by the large arrow over the observer. The relations of the air currents to the path of the storm, as previously explained, are shown by the small arrows at different altitudes above the observer. Under these conditions the northeast trade wind will back toward the north as the storm approaches. If it veers to the east the center will pass south of O_1. If it remains steady or backs to the northwest the center will pass north of O_1. The winds will constantly increase in intensity up to the hurricane at the time of the nearest approach of the center. If the latter pass over O_1 there will be an almost dead calm, lasting from fifteen to thirty minutes, depending upon the magnitude of the storm and the rate at which the center is moving. This calm will be followed by a sudden renewal of the wind from the opposite direction, and it will possibly blow with increased violence for a time, after which it will gradually abate.

Case 2: This case is about as frequent in the West Indies as case 1. The center of the storm is supposed to be at C and moving west-northwest, as shown by the large arrow for the cirrus cloud placed above the observer at O_2.

In general, in all these cases the storm center is assumed to be moving toward some one of the five positions of the observer. If he, by watching the winds or clouds, finds that the center will pass toward the right, namely, north of him, or toward the left, viz, south of him, then this diagram will enable him to ascertain in that case the winds and the changes in the winds that may be expected at his station.

Perhaps, then, the most valuable lesson to be learned from a review of the above text and figures is this, viz: The more tenaciously the surface winds cling to the north the greater is the probability of the center's passing over the observer; a strong tendency in the surface wind to change toward the east is to be construed as a sign that the storm's center will pass to the south of the observer, while a westward inclination indicates the passage of the center to the north of the observer.

Having ascertained his position with reference to the bearing of the vortex and the path of the hurricane, the observer is now prepared to take intelligent action in the matter of precautionary measures, which will be discussed under two heads: First, supposing the observer to be stationed on the land, and second, on the sea.

1. *On land.*—It would seem scarcely necessary to suggest to persons living in the "hurricane belt" the advisability of making a careful inspection of their buildings at the beginning of the hurricane season for the purpose of ascertaining the conditions of the doors, windows, and fastenings, as well as to provide materials and tools required in such an emergency and have these in a convenient place.

If a hurricane is actually approaching, the first care should be to barricade the dwelling house, and in proceeding to do this it is well to begin by barring the side exposed to the wind already blowing. If the observer has reason to believe that the center will pass over him, then extra care should be exercised in securing the north and south sides of the building, as these will be subjected to the greatest strain. When the calm arrives the time should be occupied in re-examining the fastenings on the south side to see if any have been shaken loose, as the storm will be renewed with great violence from that direction. The windows on the north side may now be opened for the purposes of ventilation. If the wind is blowing from a point considerably to westward, and the observer has reason to believe that the center will pass north of him, then he should bar the north and west sides leaving the south and east until later, provided the house is to be occupied during the storm. If the indications are that the center will pass to the south, then the east and north sides should receive first attention, leaving the south and west sides until later, with the same proviso as above.

The dwelling house being now securely barred, whatever is to be done on the outside should then be done without delay. After all possible has been done for the protection of life and property, it only remains to select a place of retreat for personal safety. The strongest and best-protected room available, whether this room be in the dwelling or not, should be selected. It is highly important, however, that this room be of easy ingress and egress without having to pass through other rooms. Should the building be endangered by the violence of the storm, and it is deemed advisable to leave it, perhaps a strong, well-built cellar, if such is available, would afford the best retreat, provided, however, the cellar is not liable to be flooded by the excessive rains which frequently accompany the hurricane. As the hurricane may occur at night it is advisable to keep a lamp burning—a good storm-proof lantern is best. To pass from one building to another in the darkness is extremely hazardous. The all-important thing under these trying circumstances is not to be found in any set of rules, but in a calm, deliberate judgment; a person who has lost self-control is totally unfit to be intrusted with the execution of precautionary measures.

2. *On the sea.*—The hurricane is without doubt one of the greatest perils of the sea. The following suggestions are offered, not that it is believed that any set of rules can take the place of good, experienced seamanship, but simply in hope of lessening the dangers by presenting suggestions that appear to be based upon sound principles. Effort is here made to point out the most dangerous and the least dangerous places and a possible method of escape, recognizing, however, that the entire management of the ship during the storm must be left to the skill of its master.

Each vessel should be provided with a barograph, or at least a barometer which should be kept in good order. During the hurricane season and when in the hurricane region, careful watch should be kept on the state of the weather; on the appearance of the slightest indication of a cyclonic formation, increased vigilance should be used, as the indications will increase in number if the storm really exists. Being satisfied that a storm does exist, it is highly important that the ship's position with reference to the bearing of the vortex be determined at once and as often thereafter as may be possible by the study of winds and clouds. Having ascertained whether he is on the right-hand or left-hand side of the path about to be described by the storm center, the navigator should study the modified form of a diagram given in Westerby's Handbook, and which is here presented as fig. 5.

For convenience, that side of the storm which is on the right hand of the storm track as one looks in the direction toward which the center of the storm is moving is called the right-hand semicircle, that on the left side the left-hand semicircle. The large arrow in fig. 5 indicates the direction and path of the storm's vortex. That portion somewhat forward and a little to the right of its center is conceded to be the most dangerous region and should therefore be carefully avoided. Supposing, now, that the captain of a vessel finds himself on the verge of a West Indian hurricane, say in the position (1) on fig. 5, and that he has sea room and a good manageable ship (of which he alone is judge), clearly he would be in very great danger should he remain in that position, as he would then experience all the fury of the gale. The proper course would seem to be to put his vessel before the wind and run with it until the wind blows from the northwest quarter, and he may then lie to on the port tack to avoid being carried around the center, or he may follow the general rule and lie to on the starboard tack; which necessarily carries him away from the storm's center.

Next consider a ship in the position (2) which is the position of greatest danger. It is very difficult to say just what is the best course to

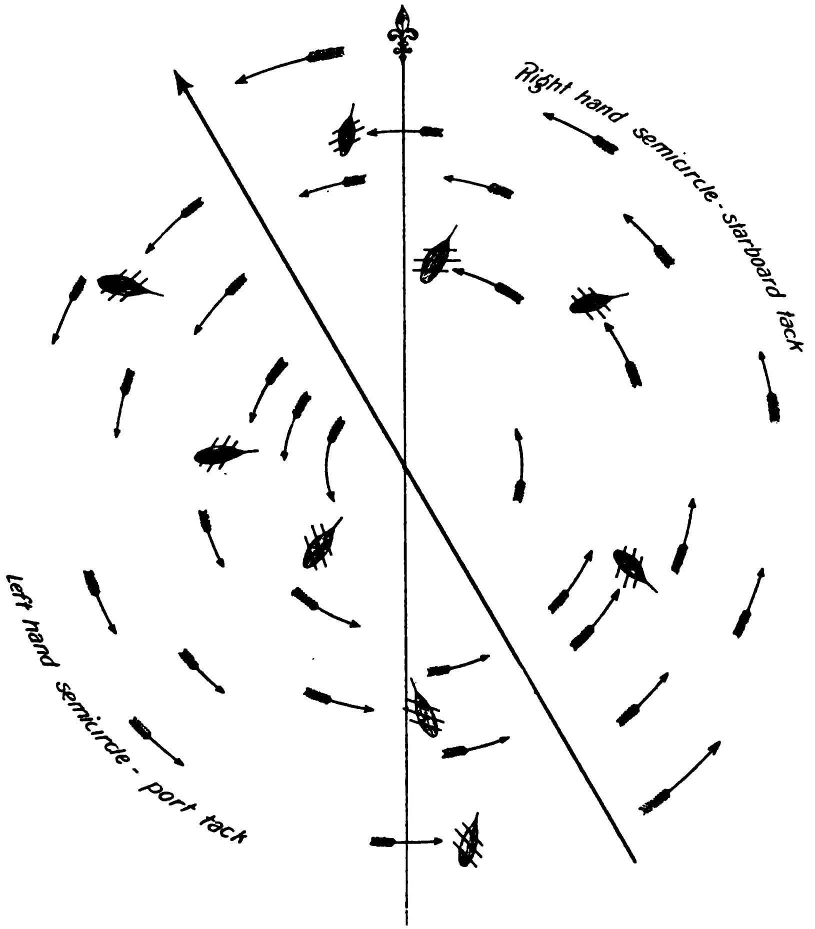
Right hand semicircle - starboard tack
Left hand semicircle - port tack

FIG. 5.

follow when in this position, but it would seem to be wise to make for the north or northeast with all possible speed, and should the wind be found coming from a more easterly direction this should be taken as a good omen and the course may then with safety be directed more to the northeast. If, however, the violence of the winds renders it necessary to lie to, this should be done on the starboard tack. By all means avoid running before the wind.

If in the position (3) fig. 5, the vessel might be allowed with perfect safety to run with the wind so long as she is permitted to keep a southeast or a south-southeast course, and then she may be allowed to lie to on either tack.

A vessel in the position (4) fig. 5, may lie to on the starboard tack or make as much northing as possible, and, if in the position (5) either make for the south or lie to on the port tack.

A quotation from Colonel Reid is appropriate in this connection. He says:

> When a vessel is lying to, and the wind veers by the ship's head, she is in danger of getting sternway, even when no sail is set; and it is supposed that vessels have often foundered from this cause. When the wind veers aft, as it is called, or by the stern, this danger is avoided.

Again—

> If it is desired to lay a ship to in a revolving storm, so that she will come up to the wind instead of falling off from it, the rule will be, when in the right-hand semicircle, to heave to upon the starboard tack, and when in the left-hand semicircle to heave to upon the port tack.

The following suggestion is taken from Davis's Elementary Meteorology, page 189:

> A modern addition to the older rules for diminishing the danger of storms at sea is to spread oil on the waves, whereby their height is lessened and they break less frequently over the vessel. Even a small quantity of oil allowed to drip from a bag hung over the vessel to windward has been found by repeated experiments to be of great service. The oil greatly diminishes the combing of the waves.

CHAPTER IV.

BAROMETERS: THEIR CARE AND THEIR USE.

The barometer occupies such a prominent and important part in any discussion of the hurricane as not only to justify but even to demand a more extended notice of this instrument. It is not necessary, however, to enter into a detailed description of the mechanism of the various forms of barometer now in use. Modern ingenuity has brought this instrument up to its present state of remarkable perfection. The most common forms of the barometer are the mercurial and the aneroid. These only will be noticed in this connection.

1. The mercurial barometer is the only form of acknowledged scientific value, as it alone is capable of giving atmospheric pressures with the requisite precision. A very practical and satisfactory form of the mercurial barometer is that provided with the Fortin cistern. This pattern, as made by Green, of Brooklyn, N. Y., is in quite general use throughout the United States Weather Bureau Service. It consists of a glass tube about thirty-four inches long and one-fourth of an inch inside diameter, protected by a thin metal tube so made as to expose the top of the mercury column, and is provided with a scale of inches and tenths and vernier by which to read to hundredths of an inch. The cistern is an ingenious device for changing the level of the mercury in the cistern so as to adjust it to a fixed point, thus enabling one to detect at the top the smallest changes in the length of the whole column of mercury. This barometer should be set up in a place subject to slight changes in temperature, and should be placed and kept in a vertical position.

2. The next form to be noticed is that commonly known as the aneroid or holsteric barometer; the former term signifying "containing no liquid," and the latter "wholly of metal." This instrument for practical purposes is a really excellent one, and many arguments may be justly stated in its favor. A good aneroid from a responsible maker, if kept in order, will answer all ordinary purposes; that is to say, it will indicate, more or less accurately, the character and amount of barometric changes from day to day. Strange to say, it seems never to occur to some people that this delicate instrument could possibly

become deranged, and that it must be subjected to a careful inspection occasionally. As with a watch so with an aneroid—a really first-class instrument may become absolutely unserviceable through neglect. It is unreasonable to expect good service from such a delicate instrument under neglect or bad treatment. These barometers should be tested and possibly cleaned and oiled occasionally. The principal defects are the lack of perfect balance in the various parts, friction and looseness in the joints and bearings; all of which must be guarded against. High temperatures have a damaging effect upon the aneroid by weakening the composition metal of the vacuum chamber and the steel spring, so that what appears to be a rise in the air pressure may be due to the weakening of the spring on account of high temperature. This instrument should therefore be placed where it will not be subjected to great changes in temperature. On the face of an aneroid the word "compensated" is sometimes printed, meaning that the evil effects of temperature have been provided against in some way, but unfortunately the compensation is often very imperfect and can not be relied upon.

In this connection it is appropriate to give Professor Marvin's "Test of the condition of aneroid." He says:

> Aneroids, seemingly good, are often defective, because some of the joints of the levers and pivots are too tight, causing the hand to stick and not move with the perfect freedom it should. The condition of an aneroid can be quickly tested in this respect by tapping the instrument on the side or bottom with the fingers or knuckles, or perhaps better by lifting the instrument about one-fourth of an inch from the table or cane-seated chair and replacing it somewhat sharply. Under this treatment, if the levers and joints are perfectly free, the hand will jump away from its position and return quickly with a vibratory and quivering movement, returning accurately to its original position. If the instrument is defective the hand in some cases will not respond to the slight knocks, or will do so without exhibiting any vibratory, quivering movement, or, especially upon being first disturbed, it will move some, but will not return to its original position.

Richard barograph.—A self-recording aneroid barometer has been devised by Richard, of Paris, and is now very widely used on vessels at sea as well as at stations on land. This instrument does not cost any more than a standard mercurial barometer and has the great advantage of enabling any one to see at a glance whether the pressure is rising or falling, and whether it has fallen so much as to indicate the presence of a hurricane. The barograph is a great additional safeguard against the sudden unheralded approach of a hurricane.

In order to appreciate fully the meaning of barometric changes one must find out the normal variations for any particular locality. The barometric gradients undergo very small changes within the Tropics. During the first half of the year the readings are a little above the yearly mean, and during the last half a little below the mean. In addition to these seasonal or annual variations there are other and more important daily changes, which take place hour after hour about as shown in the following table, viz:

Table showing diurnal barometric changes at San Juan, P. R.

[Local standard seventy-fifth meridian time.]

Hour.	June.	July.	Aug.	Sept.	Oct.	Remarks.
1 a. m	29.988	29.978	29.964	29.930	29.879	Falling barometer.
2 a. m	29.980	29.969	29.955	29.918	29.869	
3 a. m	29.980	29.968	29.951	29.913	29.863	Morning minimum.
4 a. m	29.982	29.969	29.953	29.917	29.866	Rising barometer.
5 a. m	29.989	29.977	29 959	29.927	29.875	
6 a. m	29.999	29.990	29.969	29.938	29.888	
7 a. m	30.007	29.998	29.976	29.951	29.901	
8 a. m	30.012	30.003	29.982	29.962	29.913	
9 a. m	30.014	30.007	29.987	29.967	29.921	Morning maximum.
10 a. m	30.012	30.007	29.987	29.963	29.915	Falling barometer.
11 a. m	30.007	30.003	29.981	29.952	29.899	
12 m	29.998	29.995	29.972	29.935	29.881	
1 p. m	29.986	29.983	29.958	29.917	29.861	
2 p. m	29.976	29.971	29.946	29.905	29.850	
3 p. m	29.966	29.961	29.939	29 898	29.847	
4 p. m	29.965	29.959	29.937	29.990	29.852	Afternoon minimum.
5 p. m	29.972	29.962	29.942	29.905	29.856	Rising barometer.
6 p. m	29.982	29.971	29.953	29.919	29.869	
7 p. m	29.996	29.983	29.965	29.932	29.884	
8 p. m	30.006	29.993	29.978	29.946	29.898	
9 p. m	30.014	30.003	29.988	29.956	29.904	
10 p. m	30.020	30.007	29.992	29.956	29.906	Evening maximum.
11 p. m	30.014	30.001	29.985	29.951	29.898	Falling barometer.
12 p. m	30.002	29.990	29.974	29.942	29.810	
1 a. m	29.988	29.978	29.964	29.930	29.879	
2 a. m	29.980	29.969	29.955	29.918	29.869	
3 a. m	29.980	29.968	29.951	29.913	29.863	Morning minimum.
Monthly mean.	29.994	29.985	29.966	29.934	29.883	

This table is based upon a record of three years, except for June, where only two years' record was used. The readings are from Richard's local standard barograph, seventy-fifth meridian time, and have been reduced to sea level. These variations are slight, but under ordinary conditions very regular. As may be observed from the above table, the average daily range is less than one-tenth of an inch. Any irregularity in the variations of the barometer from those just indicated should excite one to greater watchfulness, bearing in mind, however, that a north wind causes a rise in the barometer, while a south wind depresses it. If the barometer does not rise at the time it should, as indicated by this table, this is equivalent to a fall, and if it can not be accounted for as due to a south wind it must be regarded as suspicious; a falling barometer with a north wind is alarming. If the barometer does not show the diurnal changes as above indicated, the instrument must be regarded as very defective. Persons living in the hurricane region should either possess or have ready access to a good barometer and should make themselves familiar with its changes and the meaning thereof. It is a surprising fact that this instrument, invented in 1643, only came into use in the West Indies two centuries later. Westerby says:

> It is a most remarkable circumstance that in the year 1831 the use of the barometer in giving notice of the approaching storms appears to have been little known or regarded in Barbados. Colonel Reid tells us that the only information he was able

to obtain relative to the fall of the barometer during the great hurricane in that island on the night of the 10th of August, 1831, was from a note written by Lieutenant Byrne, Fort Adjutant, in which he states that by 4 o'clock on the morning of the 11th, about the time the center of the storm was passing the north part of the island, the barometer had fallen below 28 inches, the average [normal] height being about 30 inches.

In an appendix to an interesting account of this hurricane, published in Barbados, there is a meteorological journal in which the height of the thermometer is given three times a day, but the barometer is never once mentioned. How the writer of that journal could be at all acquainted with meteorology, and not know the use of the barometer, is a matter of surprise.—Hand Book of the Hurricane Season, by G. W. Westerby, page 20.

CHAPTER V.

UNITED STATES WEATHER BUREAU IN THE WEST INDIES.

Although the essential laws upon which the West Indian hurricane is formed and moves have been known to meteorologists for a number of years and the necessity for warnings of the approach of these storms has been long recognized, yet, strange to say, there was never any extensive, systematic effort on the part of the nations most vitally concerned to collect the requisite data upon which to base a forecast and to issue and distribute the same for the benefit of the interests involved until the year 1898. In that year the Government of the United States took the matter in hand and appropriated the necessary funds for the establishment and maintenance of a sufficient number of thoroughly equipped meteorological stations in the West Indies to supply ample data for forecasting the hurricane as well as ample means for the distribution of all information relative thereto. This work, as undertaken by the United States Weather Bureau, was to some degree in the nature of an experiment, but the results accomplished during the three years of the existence of this branch of the service seem to have demonstrated beyond question the wisdom and the eminently practical value of the step taken. While the immediate and chief cause of this move on the part of the Government of the United States was the protection of its own interests, yet the benefits were not to be confined thereto, but the people and commercial and marine interests of all nations were to share the same on equal terms with the United States. The Bureau spares neither pains nor expense to protect and save, if possible, life and property without distinction of nationality. Hence a few words as to the modus operandi of this branch of the service may be helpful as leading to a better knowledge and a fuller appreciation thereof.

The United States Weather Bureau now (1901) maintains fully equipped stations at the following places in the West Indies, viz: Havana, Cuba; Cienfuegos, Cuba; Puerto Principe, Cuba; Santiago de Cuba, Cuba; Kingston, Jamaica; Santo Domingo, Santo Domingo; San Juan, Porto Rico; Basseterre, St. Kitts; Roseau, Dominica; Bridgetown, Barbados; Port of Spain, Trinidad, and Willemstad, Curaçao. These stations are in charge of trained observers and observations are made twice daily, at 8 a. m. and 8 p. m., seventy-fifth meridian time, throughout the year.[a] During the hurricane season, June to October, inclusive, the morning observations are cabled promptly to Havana, the central station for the West Indian service. From Havana the combined reports are cabled to the central office at Washington. In addition to the reports from the regular Weather Bureau stations above mentioned, reports are received daily from British stations at Turks Island, West Indies; Nassau, New Providence; Hamilton, Bermuda, and from some along the Mexican coast. It will thus be seen that the region known as the "Great Bay of North America" is fairly well covered by these reports. The station at Havana, and in fact the entire West Indian service, is in charge of a forecast official under whose directions these reports are properly tabulated and charts drawn showing at a glance the general conditions existing over the region covered by the reports at the hour of observation. From this chart the forecaster can readily detect serious or significant departures from normal conditions and advise accordingly. It is scarcely possible for a severe storm to move over the Carribean Sea or the Gulf of Mexico without being detected at one or more of these stations. A storm approaching from the east is very apt to be detected some time in advance by its precursory manifestations at one or more of the outlying stations. The existence and location of a West Indian hurricane once determined, its subsequent movements are closely watched and all threatened districts forewarned so far as possible in ample time to take precautionary measures.

In deciding upon the most efficient means of serving the people, the Bureau deemed it best to issue two, and only two, kinds of messages to West Indian stations, and a failure on the part of the public in general to clearly distinguish between the significance of these two classes of messages has resulted in some confusion and unnecessary alarm. The messages issued by the Bureau are either "advisory messages" or "storm-warning messages."

1. Advisory messages are issued to such places as in the opinion of the forecaster are not threatened with dangerous conditions and are intended primarily for the benefit of mariners who may be leaving port. They are to be regarded by the public merely as a matter of information, and are not to be taken to mean that a storm is approaching. When unsettled conditions arise, and there is any evidence of the formation of a hurricane, these messages are sent out to inspire alertness on the part of observers in particular and the public in general. These unsettled conditions may and often do pass away without developing into anything serious. After the hurricane forms and starts on its devastating career these messages are sent out to reassure and inform

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[a] These arrangements have been altered by an order issued in January, 1902.

places not endangered. No signal whatever is displayed upon the receipt of an advisory message.

2. Storm-warning messages are issued whenever, in the opinion of the forecast official, a place is likely to be visited by dangerous conditions, and the hurricane signal—two red flags with black centers, placed one above the other—is always displayed upon the receipt of one of these messages. This message, of course, is to the public in general and means that it is advisable for all to prepare for severe weather.

Of course the Bureau is not infallible; it makes mistakes, so does the public. If, however, the efforts of the Bureau are properly understood and its messages correctly construed, its service will be more highly appreciated. It must be admitted that these advisory messages need to be worded with great care and disseminated with discretion because of a tendency on the part of the people to misunderstand them.

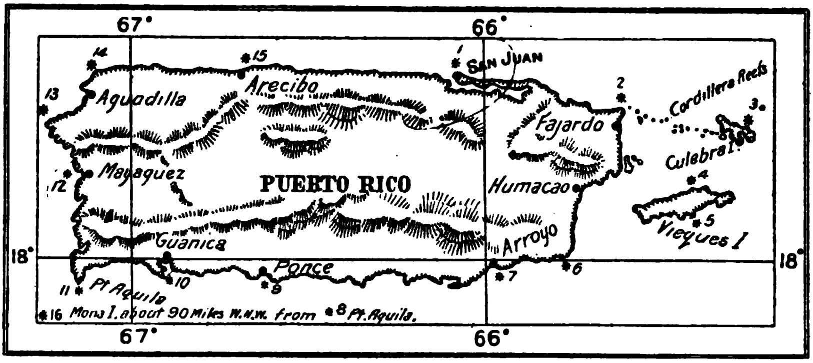

FIG. 6.

For the benefit of mariners visiting Porto Rican ports or navigating these waters, we will say a word relative to the service of the United States Weather Bureau in Porto Rico. In addition to the climate and crop work carried on in the island, a very effective local system for the distribution of information regarding West Indian storms is maintained. The central station for the island is at San Juan, from which point all messages are distributed. In the event of a storm the hurricane signal is displayed at the following places, viz: San Juan, Fajardo, Humacao, Arroyo, Ponce, Guanica, Mayaguez, Aguadilla, and Arecibo. (See map, fig. 6.) Moreover warning messages are sent to all telegraph stations on the island, and when a hurricane is expected the warning is carried by the police to the remotest parts of the island. The system is rendered doubly efficient through the generous cooperation of the insular telegraph company and the insular police force. Every effort is made to give the people a thoroughly efficient service.

Light-houses in and around Porto Rico.

Location.	Height.	Visibility.	Character.	Intervals.		Structure.
	Feet.	*Miles.*		*m.*	*s.*	
1. San Juan	171	18	W. F. & Fl	1	0	D. G. & W.
2. Cape San Juan	266	18	R. F. & Fl	3	0	D. G.
3. Culebrita	305	12	W. F			
4. Vieques, North	68	8	R. F			G.
5. Vieques, South	65	13	W. Flg	0	5	W
6. Tuna	123	18	W. Fl	2	0	W.
7. Figuras	47	12	W. F			G.
8. Muertos	297	18	W. F. & Fl	3	0	W. & L. B.
9. Ponce	46	10	R. F			W. & B.
10. Guanica	119	8	W. F			
11. Cabo Rojo	128	18	W. Rev	1	0	G.
12. Mayaguez	12	3	R. F. 2			
13. Jiquero	69	8	W. F			
14. Borinquen	65	14	R. & W. Fl	0	30	R.
15. Arecibo	120	16	W. F			W.
16. Mona	235	20	W. Rev	3	00	Bl.

NOTE.—The visibility is calculated for an elevation of fifteen feet above sea level, and is given in nautical miles. B signifies blue, Bl. black, D dark, G gray, L light, R red, W white, F fixed, Fl. flash, Flg. flashing.

The height is in feet above sea level. The intervals between the flashes are given in minutes and seconds of time.

This table is taken from First Annual Register of Porto Rico, 1901, page 26.

CHAPTER VI.

PORTO RICO AND ITS HURRICANES.

This island was known among the Indians by the name Borinquen, but when discovered by Columbus on November 16, 1493, he gave it the name San Juan Bautista, in honor of John the Baptist. Ponce de Leon, the discoverer of Florida, was its first governor. He took charge in 1509, establishing as his capital the town of Caparra (now called Pueblo Viejo), some 3 miles inland from the bay of San Juan. He afterwards changed his capital from Caparra to what is now San Juan, because the latter site could be more easily fortified and defended against the attacks of unfriendly Indians. He called his new capital Puerto Rico; subsequently and in some unknown way the island and the town changed names and to-day we call the island Porto Rico and the town San Juan. Spanish rule prevailed from the settlement (1509) down to 1898, a period of nearly four hundred years. The history of this period is a rather monotonous sequence of unimportant not to say uninteresting events.

The island is situated between latitudes 17° 50′ and 18° 30′ north, and longitudes 65° 30′ and 67° 15′ west. It is rectangular in shape, being about 100 miles long by 36 wide, and contains, approximately, 3,600 square miles. The census of Porto Rico, 1899, p. 11, says:

> Passing across it from east to west, a little south of the middle of its breadth, is a broken, irregular range of hills or low mountains, which toward the eastern end trends northeastward, and terminates near the northeastern corner of the island, where it culminates in the peak of El Yunque, 3,609 feet in altitude. Elsewhere it ranges in altitude from 2,000 to 3,000 feet, with occasional summits slightly above 3,000 feet and gaps slightly below 2,000 feet. This range is known in different parts of the island by various names, Cordillera Central, Sierra de Cayey, and in the northeast Sierra de Luquilla. From its crest the land slopes northward and southward in broad undulations, deeply cut by streams, giving most of the interior of the island a steep, hilly surface, gradually becoming more nearly level until near the coast it spreads into broad, level playas. This range forms the water divide of the island, and from it streams flow northward and southward, those flowing north having much the longer courses and gentler slopes. None of these streams are navigable, excepting for a very few miles near their mouths, where they are in effect estuaries. The largest are the Rios Loiza, Bayamon, Morovis, Arecibo, and Blanco, all on the north of the dividing ridge. On the south the dividing ridge descends steeply, with short spurs to a narrow coastal plain. Here the streams are short, with very steep descents.—Census of Porto Rico, 1899, p. 11.

About 24 per cent of the area of the island is under cultivation, the principal crops being sugar cane, coffee, and tobacco.

With these introductory remarks we will proceed with the chief aim of the chapter—the presentation of a few facts concerning some of the most destructive hurricanes which have visited the island. No little difficulty has been experienced in compiling the following list, owing to the fact that early chroniclers of Porto Rican events paid only incidental notice to these visitations, oftentimes passing them by with a mere mention. Only the unusually destructive ones received a detailed treatment, and this, of course, in a descriptive way. The data given below are taken from various sources, and are believed to be as complete as existing records warrant. In translating the Spanish into English the chief aim has been to give all the material facts only; hence the accounts are not to be regarded as efforts at literal or even full translations.

The principal authorities consulted were: Memorias de Puerto Rico por D. Pedro Tomas de Córdova (referred to as "Mem."); Historia de Puerto Rico por José Julian de Acosta y Calbo (referred to as "Hist. de P. R."); Efemerides de la Isla de Puerto Rico (referred to as "Efem."); West Indian Hurricanes, Bulletin H, by Professor Garriott (referred to as "B. H.").

1515, July.—The royal officers reported to the spanish king that a storm had caused the death of many Indians.—Hist. de P. R., p. 433.

1526, October 4.—Dr. Juan de Vadillo describes this storm thus: On the night of October 4 there began on the island such a storm of wind and rain, called here a hurricane, as to destroy the greater portion of this city, and to do great damage to the estates in the country by overflowing the rivers. The loss can not be estimated; many rich have become poor, among them Pedro Moreno, the lieutenant-governor.—Hist. de P. R., p. 433.

1527, October 4.

1530, July 26, August 23, August 31.—Within a month and a half there have been three hurricanes, which have destroyed all farm work, drowned many cattle, and created great distress among the people. In San Juan half the houses were blown down and the best of those remaining had no roofs. Not a house was left standing in the country. All have been left poor and now wish to leave the island.—Hist. de P. R., p. 123.

1537, July and August.—Within two months we have suffered from three hurricanes, the greatest ever experienced. As the plantations are situated along the rivers, the crops were destroyed by the overflow. Many slaves and cattle were drowned, great destitution prevails, and the desire to leave the island is now more general.—Hist. de P. R., p. —.

1568, August 24.

1575, September 21.—(San Mateo.)—Hist. de P. R., p. 434.

1615, September 12.—This was the severest hurricane of the forty years following that of San Mateo. It did so much damage to the cathedral that it was necessary to cover a portion of it with grass [thatch] until aid could be received from the King.—Hist. de P. R., p. 434.

1738, September 12.—On this day the island was visited by one of those storms which have ever caused such ravages. The hurricane destroyed the crop of wild fruits—the main support of the swine and other animals. The sudden overflows drowned a great number of live stock; the citizens of Ponce and Coamo abandoned those places because of the misery to which the storm reduced them; they were compelled to eat unwholesome roots, which caused much sickness, and as the Government allowance (for relief) for that year was exhausted, the treasury was bound in the sum of 50,000 pesos, which fact aggravated the situation and made it less possible for the Government to succor the needy and restore the loss. The storm was followed by another very serious calamity in the form of a plague of worms, which seemed to originate in the mud-covered swamps and destroyed all seeds as fast as planted.—Mem., v. 3, p. 22.

1740.—A hurricane destroyed a palm grove 5 or 6 leagues in extent at Ponce.—Hist. de P. R., p. 434.

1751, August 18.—No details.

1766, September 19.—No details.

1766, October 7 and 8.—This hurricane left in ruins the following towns, viz: Cangrejos, Rio Piedras, Loisa, Fajardo, Caguas, Las Piedras, and Guayama; all crops of rice, corn, and yucca were destroyed; overflowing rivers did great damage; the houses and huts in the country were destroyed or badly damaged; no fruit trees were left standing; the roads were rendered impassable; many ships were wrecked and the few that escaped the storm were used by the Government in the saving of life and property and carrying aid to the destitute. Without the least doubt this is one of the most destructive hurricanes that has visited the island.—Mem., v. 3, p. 29.

1767, August 7.—Porto Rico experienced a strong gale which destroyed the plantations, and much live stock perished in the overflowing rivers. This event and the lack of funds for relief placed the people in the same miserable state as the year before.—Mem., v. 3, p. 31.

1772, August 31.—The convent of Santo Domingo, Forteleza de Santa Catalina, the chapel at Moro, and many other buildings were unroofed and many buildings materially damaged. Six ships were sunk and eight others stranded; all crops destroyed and many animals perished. Roads were rendered impassable.—Mem., v. 3, p. 36.

1775, August 1.—A furious hurricane.—Mem., v. 3, p. 40.

1776, September 7.—A strong hurricane.—Efem., p. 92. Mem., v. 3, p. 40.

1780, June 13.—A hurricane caused great destruction of property, especially of crops. An English war ship driven from St. Lucia was wrecked on the coast of Guayama.—Mem., v. 3, p. 42.

1785, September 25.—A furious hurricane passed over the island.—Mem., v. 3, p. 5. Efem., p. 94.

1788, August 16.—B. H., p. 24.

1804, September 4.—A great hurricane.—Efem., p. 91.

1804, September 21.—A great hurricane known as "San Mateo," which long remained in the memory of the people.—Efem., p. 94.

1806, September 11.—The south portion of the island experienced the severest hurricane for many years past; many churches and a large portion of the houses in that section were damaged; fruit trees destroyed; rivers overflowed their banks, destroying much property. At San Juan shipping suffered much loss.—Mem., v. 3, p. 153.

1807, August 17, 18, and 19.—The island again suffered the disasters of a severe hurricane from the east which lasted fifty hours. Thirty-six rivers overflowed, destroying much property and live stock. Three Danish ships which were anchored at St. Croix were stranded on the coast of Porto Rico and an English cutter of 18 cannon which was cruising between Porto Rico and Vieques was wrecked and only one of the crew saved.—Mem., v. 3, p. 154.

1809, September 2.—B. H., p. 24.

1812, July 23, August 21.—Heavy gales did considerable damage to crops.—Mem., v. 3, p. 183.

1813, July 23.—The storm of this year was most severe at San German and Yauco.—Hist. de P. R., p.

1814, July 23. No details.

1814, August 11.—For an account of this hurricane see "Diario Economico del Intendente Ramirez" of August 11, 1814—Hist. de P. R., p. (I was unable to find the book referred to.—W. H. A.)

1816, (?) 18, 19, and 20.—A hurricane of extraordinary violence visited the island this year. In the port of Caborojo three ships were wrecked and a portion of the crew perished. In the town of Tuna the wind destroyed 72 houses and seriously damaged crops. Two persons were killed and a great number of cattle. In the village of San German the overflowing river destroyed 101 houses, 82 head of cattle, 6 horses, 119 hogs, and many domestic birds. In many other towns of the south and west portions of the island there was great destruction of property.—Mem., v. 3, p. 258.

1819, September 21 and 22.—In the midst of so many afflictions occurred one of the most dreadful and destructive of the hurricanes that have visited the island. It began on the night of the 21st and ended at midday of the 22d. The people were thrown into the greatest confusion and were reduced to the greatest misery. All the ships that were in port were wrecked; the greater part of the houses both in the town and in the country was destroyed, crops were ruined, sugar and coffee mills were destroyed; the whole presenting a sad picture of desolation.—Mem., v. 3, p. 355.

1825, July 26 and 27.—(Santa Ana.) On the night of the 26th and 27th, the island was visited by one of those terrible manifestations of nature occasioned by the winds which frequently change the face of the earth, chiefly in Arabia and Africa, and which are a scourge in the Antilles, Madagascar, and many other countries.

Two days before copious rains had been experienced and early in the morning of the 26th violent gusts of wind had been felt; but the atmosphere cleared up at intervals and the only indication during the day of the weather that set in at night was the excessive heat felt at those intervals when the rain ceased. At 8 p. m. the sky began to be overcast with dense clouds and the wind grew stronger and from the summits of the mountains of Luquillo serpentine flames of fire seemed to issue. Lightning flashes became more frequent and the rain fell in torrents. At 11 p. m. there was no doubt that a terrible hurricane was on. The clouds which could be distinguished in the zenith had in their centers dark spots and were bordered with a copper color. The winds were gradually increasing in strength.

From the afternoon, according to the best informed, the wind blew from the east and northeast, but at 11.30 p. m. it began with greater fury than ever from the same directions, inclining a fourth more or a fourth less in the quadrant mentioned until 2.15 a. m., when it changed to the north-northwest, where it remained until 2.45 when it suddenly shifted to the southwest and successively to the south, south-southwest, and southeast, where it remained until 8.30 a. m. of 27th, after which it abated.

The devastations were extraordinary in some places. The governor's palace was badly damaged, the San Antonio bridge and other public and private buildings were thrown down and two suburbs almost entirely wiped out. All communication between San Juan and the island was destroyed, a part of the city wall suffered damage; the lightning rod on the powder magazine was destroyed; also many doors and windows. All the ships in the bay were driven aground. The towns on the south and west portions of the island did not suffer much but those in the north and east sustained great loss. An offical report gives the losses as follows, viz:

Total deaths	374
Total injured	1,210
Houses blown down	6,710
Live stock killed	2,560
Fowls killed	11,345

Many crops destroyed.

Total value of property lost, 481,112 pesos.

(This is one of the truly historic hurricanes of the island.—A.)

1827, August 17.—A hurricane caused great loss of crops, loss of five ships at Ponce, 3 at Guayama, 2 at Humacao, 1 at Mayaguez, and 1 at San Juan. Not a plantain tree remained.—Mem., v. 5, p. 201.

1837, August 2.—(La Reina de Los Angeles: The Queen of the Angels.) This hurricane was remarkable for its excessive violence. It lasted only five hours, during which time all the ships in the harbor of San Juan were wrecked and great damage done to property throughout the island.—Hist. de P. R., p. 434.

1851, August 18.—A rather mild hurricane; caused some damage.—Hist. de P. R., p. 434.

1852, September 22-26.—B. H., p. 25.

1867, October 29.—(San Narciso.) We now come to a consideration of one of the most remarkable, if not the most remarkable hurricane in the annals of Porto Rico, that of San Narciso. The following notes are taken from a work entitled La Memorable Noche de San Narciso, por Don Vicente Fontan y Mera, published in 1868, the year after the hurricane. The order of treatment here followed is the same as in the work above referred to; that is, brief extracts from the reports (mainly official) from the various towns on the island. This storm appears to have passed diagonally across the island, the center passing over Caguas, a town in the east central part of the island. The injured towns are described in alphabetical order, as follows:

Adjuntas.—Storm began at 8 p. m. with strong gusts of wind from the north; afterwards from the east; finally from the south, from which direction it blew most furiously until 3 a. m., when it began abating. There were 2 deaths; 300 houses, a large portion of the huts, and 4 bridges destroyed.

Aguada.—Storm began at 9 p. m., accompanied by heavy, copious rains, thunder, and lightning. At 1 a. m. the wind was blowing furiously from the south, but by 3 a. m. it had abated. Very few of the houses were able to resist the fury of the winds. More than two-thirds of the houses were rendered useless. One death.

Aguadilla.—Day began serenely. At 7 p. m. the sky was covered with dark clouds and light showers began to fall. By 10 p. m. the wind was so heavy that it threatened to destroy all. The people of the village became terrified; the lamentations of those living in the country could be distinctly heard; those living near the sea were thrown into great consternation by the terrifying noise of the sand carried by the winds and falling upon the roof. One death; 1 stone house, nearly all the wooden houses, and all the huts were thrown down.

Aguas Buenas.—Torrents of water came from the hills; the force of the wind moved the very foundations of the houses; the church, houses, huts, and plantations of cane, rice, coffee, and corn were handled in a most horrible manner, and on every side were to be seen lakes, mud, wreckage, and misery. There were 11 deaths.

Aibonito.—As the night approached the wind was fair, but in a very short time it began to blow with great fury; at 7 p. m. the town was completely enveloped in the horrors of a terrible hurricane. There were 4 deaths.

Añasco.—There was 1 death and great loss of property.

Arecibo.—There was 1 death; some houses unroofed; many huts thrown down, and 1 ship damaged.

Arroyo.—The day broke clear and calm. At 2 p. m. it began to grow dark. All observing persons noticed this strange phenomenon and concluded at once that something serious was about to happen. The barometer pointed to "hurricane;" the sea was heavy; the winds continued to increase in strength, and by 6 p. m. the town was suffering the full effects of a horrible hurricane. The wrath of the elements did not cease, and profound darkness reigned everywhere. The streets were deserted, and only the sound of the hammer could be heard—a sure sign that the people were making fast doors and windows. In the suburb of Guamany almost all the houses were thrown down. By 10 p. m. the hurricane was over. Two persons were wounded and many large houses unroofed.

Barranquitas.—The effects of the hurricane were terrible People of the town who have memories of the storm of the "Queen of the Angels" affirm that the calamities of 1837 can not be compared with those of 1867. The winds blew from the west during the p. m., but toward night changed to the southeast, and then began the devastations of the hurricane. Darkness, thunder, ligntning, and the noise of the wind clothed nature with a false aspect. It seemed that the rushing of the waters and the whirling of the winds would destroy all. On the following day were to be heard only the wailings of the unfortunates. The coffee crop, the hope of the farmer, was ruined. There were 5 deaths, 20 wounded, and 300 houses and 550 huts thrown to the ground.

Barros.—Hurricane began at 6 p. m. of the 29th and lasted until 1 a. m. of the 30th. At 9 p. m., when the wind was at its worst and the people were already thoroughly confused, they were suddenly made to realize that they were surrounded on the south, west, and north by the waters from the river. They now became panic stricken. The water rose 6 varas above its normal level.

Bayamon.—Six persons perished and 14 were more or less seriously hurt.

Caguas.—During the morning the heat was suffocating—very unusual for the season. At noon the sky began to be overcast with dense leaden-colored clouds, which continued to gather, so that by 4 p. m. the town was enshrouded in darkness. At 5 the action of the wind and the falling of the barometer indicated the approach of a hurricane. The gusts of wind continued to increase in violence, so that by 7:30 p. m. the force of the wind was almost irresistable. At the beginning the wind blew from the north, and after a calm of 10 or 12 minutes it changed to the southeast. The hurricane was now on in all its fury. The rain fell in torrents, the wind shook the houses in a most frightful manner, buildings were stripped, the tiles were carried to great distances, great trees were uprooted, and walls of masonry razed to the ground. To complete the awful scene there was a shaking of the earth sufficiently severe to reduce to rubbish some of the interior walls of the best dwellings and the most solidly constructed. The hurricane lasted in all its fury until 9.30 p. m. and was entirely over by 11 p. m. The rain continued until 1 a. m. Eleven persons were killed, 103 wounded, many stone buildings damaged, nearly all the wooden ones unroofed, and most of the huts blown down.

Carolina.—One person killed, 6 wounded, the church damaged, 1 stone house blown down, many unroofed, and almost all the huts demolished.

Cayey.—The wind first blew from the northwest; rain fell in torrents; by 8 p. m. it was evident that a true hurricane was on. The noise of the water which fell like a cataract, the continuous lightning flash, and the impenetrable darkness inspired the gravest apprehensions. As fright and confusion occupied the minds of all, it was not possible to tell how long the wind blew from the west, but it came with such force as to strip and uproot the great trees and destroy many houses. From the west the wind shifted to the south, from whence it seemed to come with all the fury of the infernal regions, so much so that it seemed as if the hour of total destruction of all things had come. No one is able to give a correct idea of those hours of terror, fright, consternation, and death. Only 2 deaths reported.

Ceiba.—The oldest inhabitants affirm that this hurricane for its duration, intensity, and ravages makes less memorable that of Santa Ana. Many houses were rendered useless and 77 huts destroyed.

Ciales.—The terrible event of this day has spread desolation and misery in this town. The morning appeared rainy and the sky was overcast with dense clouds. At 6 p. m. the winds came in light gusts; at 10 the storm began, and then there was presented to view a picture of horrible desolation. The doors and windows were lifted from their hinges, and the people in desperation ran quickly hither and thither seeking a place of refuge, but finding none. In a word, chaos reigned among the people.

The storm lasted six hours and was most destructive during the first part. Mothers with their children on their backs might be seen endeavoring to find a place of safety to escape death. The darkness was so intense that it was impossible to discern objects, and only by the agonizing cries of the victims could they be located in order to render aid. There were 3 deaths and 29 wounded; all the houses were blown down.

Cidra.—At 7 p. m. the wind began to blow from the northwest. Soon after it developed hurricane force, lasting four or five hours. The earth trembled, the noise of flying fragments of zinc torn from the roofs by the wind and carried to great distances, and the appearance of the sky filled with large clouds, presented a scene calculated to fill the minds of the people with consternation. When the light of the following day revealed the ravages of the storm all minds were filled with sorrow and pity. Four persons were killed and 14 injured; 50 houses and 340 huts were blown down.

Coamo.—The effects of the hurricane were serious. From 7 to 10 p. m. the winds lashed the town with unheard-of fury. At first the wind came from the southwest but changed quickly to the south and southeast. The first moments produced the gravest fears. Black clouds covered the whole sky and perfect darkness reigned. The peals of thunder and the lightning flashes on this sad night increased the alarm. There was one death, four injured, and some property lost.

Corozal.—At 7:30 p. m. the wind began to rage with frightful fury. The noise of the elements produced terror and consternation; perfect darkness prevailed everywhere, and only by the momentary flash of lightning were the frightful scenes revealed. By 9.30 p. m. the storm had nearly ceased. One death, 37 injured, and many houses damaged or destroyed.

Fajardo.—At daybreak there were some clouds, but these were not regarded as ominous. At 5 p. m. the winds began to blow in a most unusual manner and with an almost irresistible force. The water fell in sheets, inundating all; the earth trembled twice. Only the direful noise of the hurricane, the crash of falling buildings, and the cries of the unfortunates who experienced every degree of misery, from poverty to death, were to be heard. Three hours afterwards, the strife of the elements having ceased, the bravest hearts went forth seeking their families and rendering aid to the needy. The greater part of the houses was on the ground and passing along the streets was impossible because of the piles of débris which but a short time before had constituted the humble homes of the poor. There were 13 deaths and 113 injured.

Gurabo.—There were 19 killed and 40 wounded. Twenty houses and 400 huts were blown down.

Hato Grande (*San Lorenzo*).—There were 5 deaths, 13 wounded, 183 houses blown down, and more than 500 huts destroyed.

Humacao.—At 4.30 p. m. the wind began to blow from the northwest, accompanied by light showers. For a moment all believed that it was only an ordinary change, but, vain delusion, at 5 p. m. a hurricane more violent than any in the annals of this town was upon us. The wind raged in a most unwonted manner; the most solid buildings were shaken to their foundations. All houses were unroofed and many completely demolished. The wind changed to the south and an earthquake came to add terror to the scene. Profoundest darkness reigned everywhere. Few houses remained intact after the storm. One person killed.

Luquillo.—At 4 p. m. the wind blew from the north in such a manner as to give warning of an approaching hurricane. The wind increased for a time, accompanied by some rain. At 5 p. m. it shifted suddenly to the northeast. At this moment an earthquake occurred; the rain increased; the impetuosity of the wind and water was soon converted into a frightful hurricane. After 4 p. m. the people abandoned their homes and sought refuge in stronger buildings. At 5 p. m. it was not possible to resist the storm. Seven were killed and 16 wounded.

Manatí.—Nineteen persons were killed.

Mayaguez.—There were 9 deaths, 15 stone houses badly damaged, and 150 huts demolished.

Moca.—As night approached neither frequent showers nor northerly winds presaged the coming storm. Notwithstanding this, the people retired to their homes, because they were no longer able to walk the streets. Copious rains and vivid lightning foretold the coming storm. At 10.30 p. m. the thunder ceased, the rain increased, and the frightful noise of the hurricane was manifest. The storm continued its work of devastation until 3 a. m. of the 30th. Two persons were killed.

Moróvis.—At 7.30 p. m. the effects of the hurricane began to be felt. Words can not convey the consternation and confusion which prevailed. Some silly people believe that at times it rained fire; at other times, water; and the most religious, that the hour of final judgment had come. Nine persons killed and 36 wounded.

Naguabo.—Eight deaths, 48 wounded; many houses ruined; three ships sunk, cargoes lost, crews saved.

Patillas.—About 6 p. m. thousands of swallows were to be seen, the clouds were moving rapidly, and the atmosphere was heavy, so that anyone given to observing might have known by these signs that a storm was approaching. The wind blew from the northwest at first, afterwards from the southwest. Never in the memory of the inhabitants has there been felt such violence of wind, especially from 7 to 9 p. m. During those two hours of affliction and desolation many houses were wrecked and two lives lost.

Ponce.—Three killed, 32 wounded, much stock lost, and great property loss.

Rio Grande.—There were 12 deaths; more than 100 houses and 300 huts blown down.

Rio Piedras.—One killed, 3 wounded, 126 houses and 100 huts demolished.

Salinas.—At midnight of the 29th the storm suddenly came upon this town. The great trunks of the hucar were as fragile cane; the light of a meteor illuminating space for an instant inspired grave apprehensions, and all feared for their lives, because at 2 a. m. the water from the river invaded the greater part of the town. Agricultural products suffered the greatest damage.

San Juan.—At 5.45 p. m. the barometer read 29.60 inches, and such was the state of the atmosphere as to give to the close observer ominous signs of an approaching disaster. By 7.15 all the elements seemed to have been unloosed and the city was in the midst of a frightful hurricane. The darkness of the night, the torrential rains, the impetuosity of the winds, the clatter of doors and windows, and the trembling of the buildings inspired serious cares in the minds of all. On the streets were to be seen only those persons who had public duties to perform or those whom the fearful night had caught away from home and who were trying to return. These were few, however. The streets were currents of water, which the winds drove in different directions, and the hurricane from the first enshrouded the city in darkness. . The street lamps for the most part were useless, and all those who found themselves in the streets ran quickly toward their homes whenever the fury of the wind did not force them to take another direction.

The ships in the bay felt the full force of the hurricane and suffered much damage. Sr. Tosta, the captain in actual command of the port, makes the following report of the disasters among the ships, viz:

"The sloop *Carmen* was dismasted at 7.30 p. m. and was instantly sunk.

"The Spanish pilot boat *Josefita* was dismasted at 8 o'clock and went down immediately thereafter.

"The sloop *Rita* was sunk at the same hour, carrying with it the boat belonging to the captain of the port. Several trans-Atlantic ships broke away from the east wharf, where they were fastened. The rings which held the ropes were torn away.

"The Spanish brigantine *Joaquin* was driven onto a bank, but finally succeeded in getting off without serious damage.

"The frigate *Apollo* was grounded; also the English schooner *Maria*.

"The pilot boat *Fé* grounded in the arsenal and was completely dismasted.

"At 9.30 the boats belonging to the health officer and custom officer went down."

From that hour the wind began to blow from the east and the barometer to rise, and by 11.30 the wind was blowing "a fresh breeze," as is said in nautical terms.

The property loss in the city was not very considerable, owing perhaps to the manner of constructing the houses. The houses are securely joined one to another.

Trujillo Alto.—There were 13 killed, 69 wounded, and great loss of property, 12 sugar mills being wrecked.

Utuado.—From 9 a. m. there occurred at short intervals heavy showers accompanied by gusts from the north. By 9.30 p. m. the hurricane was on in all its fury. It raged until after 11 p. m. Four persons were killed and much property destroyed.

Yauco.—Very heavy, strong winds began to be felt at 5 p. m. and by 8.30 p. m. the hurricane was furiously lashing everything, destroying the cane and the coffee, the main support of this section.

Summarizing the reports rendered from 67 towns, I find there was a total of 211 deaths, 741 persons more or less seriously injured, and a total estimated property loss of 6,397,802 pesos.

(For an excellent account of this same hurricane as it affected the island of St. Thomas, see Bulletin H, p. 52 and 53.—W. H. A.)

1888, September 5.—Dr. Branch.

1889, September 4.—B. H., p. 36.

1899, August 8.—(San Ciriaco.) The following account is taken from Bulletin H, pages 53–54, and was prepared by R. M. Geddings, section director, Weather Bureau.

Porto Rico has been devastated by many hurricanes, but the records, beyond the mere statement of the facts, are very incomplete and inaccessible. Four, however, stand out prominently as having committed terrible ravages. These are the hurricanes of Santa Ana on July 26, 1825; Los Angeles on August 2, 1837; San Narciso on October 29, 1867; and San Ciriaco on August 8, 1899.

Owing to the paucity of records it is almost impossible to say which of these four was the most severe, but it is the generally conceived opinion that that of the Los Angeles was the worst. There being no meteorological data available, however, it can probably be said that the hurricane of San Ciriaco was very nearly as severe as regards the velocity of the wind, and very much more so as regards the destruction of property and life. This is probably due to the fact that in 1837 the population of the island and the number of buildings was very much less. The latter hurricane having also occurred while a station was in operation in San Juan, we are enabled to present meteorological data which is entirely wanting in the former.

The rainfall during San Ciriaco was excessive, as much as 23 inches falling at Adjuntas during the course of twenty-four hours. This caused severe inundations of rivers, with which Porto Rico is so liberally endowed, and the deaths from drowning numbered 2,569, as compared with 800 killed by injuries received from the effects of the wind. This number does not include the thousands who have since died from starvation. The total loss of property was 35,889,013 pesos.

For several days previous to the hurricane the meteorological conditions had been peculiar. On the 3d calm was recorded at both the morning and evening observations. Between midnight of the 3d and 8 a. m. of the 4th but 4 miles of wind were recorded. The barometer showed no rise such as is usually anticipated immediately preceding a hurricane, the mean of the 5th being 29.96, and that of the 6th 29.98. During the afternoon of the 7th the sky was unusually hazy, and the lower clouds were moving rapidly from the northeast. About 3 p. m. the sky was covered with thick alto-stratus and stratus clouds, the former moving from the southeast and the latter from east-northeast. At this time the barometer registered 29.865. At 10 p. m. the barometer began its downward movement, which did not cease until the lowest reading, 29.23 inches, was reached at 8.30 a. m. of the 8th, at which time the mercury in the tube was oscillating violently.

The storm passed to the south of San Juan, and, striking the island on the southeastern part, passed in a direction north of west until it passed the northwestern part, the time consumed in its passage being from 7 a. m. until 1 p. m. The wind reached no very high velocity until 2 a. m. of the 8th. At 10 p. m. of the 7th, however, it came in puffs, some of them of considerable violence. At 5 a. m. of the 8th it was raining and blowing furiously, both increasing until between 7 and 9 a. m. the hurricane was at its height, the wind reaching a registered velocity of 66 miles an hour from the northeast. The wind shifted during the progress of the hurricane from northeast to southeast.

There was noted in the case of this hurricane, as has been noted in subsequent ones, a decided lowering of the relative humidity immediately preceding.

CHAPTER VII.

ST. KITTS AND ITS HURRICANES.

The little island of St. Kitts (St. Christopher), West Indies, was discovered by Columbus in 1493, was settled by the English in 1623 and soon afterwards by the French, with whom the English generously divided the island. It has more than once been a factor in international disputes and much blood and treasure sacrificed for its possession. It finally, however, came into the undisputed possession of England, and there remains to this day. St. Kitts boasts of the fact that she is the oldest English colony in the West Indies and that from her many of the others were settled.

The main body of the island has an oval form, from the southeast end of which runs a narrow neck, gradually expanding into a small knob. The total length of the island is 23 miles and the breadth of the main body or oval about 5 miles, giving a total area of 68 square miles. The central part of the main body is occupied by a range of lofty rugged mountains traversing it from southeast to northwest and attaining its greatest height, 4,100 feet, at Mount Misery, with a secondary elevation of about 3,200 feet near the southeastern end. The mountains appear to be crowded together and are intersected by rocky precipices. The circle of land formed by the skirts and lower slopes of the mountains of the main body of the island and the valley of Basseterre constitute nearly the whole of the arable and cultivated portion of the island. These tracts of land are covered with sugar plantations and dotted over in every direction with homesteads, mills, and laborers' villages. The higher slopes of the mountains are clothed with short grass, affording excellent pasturage, while their summits are crowned with dense woods. The island is unquestionably of igneous origin; the soil is a dark gray loam, very porous, and one of the very best in the West Indies for the production of sugar. The climate is dry and healthful, being tempered and purified by the winds, electric storms, and hurricanes to which the island is exposed because of its position. The evenings and mornings of the hottest days are pleasantly cool. The coolest months are January and February, the warmest, August.

In the present chapter we have collected as much information as could be had relative to the hurricanes and floods of the island which, because of their excessive violence and disastrous consequences, have found their way into records of one form or another. Details are always given if accessible.

The abbreviations used in this chapter in referring to the authorities for the various accounts are as follows, viz:

S. C.—Southey's Chronological History of the West Indies.
B. H.—Bulletin H, U. S. Weather Bureau, by Professor Garriott.
W. J. B.—Dr. W. J. Branch, of St. Kitts.
Notes.—A miscellaneous collection of notes.

The accounts of the two hurricanes of 1899 were written by myself and were first published in the Monthly Weather Reviews for August and September, 1899, where more extended accounts may be found

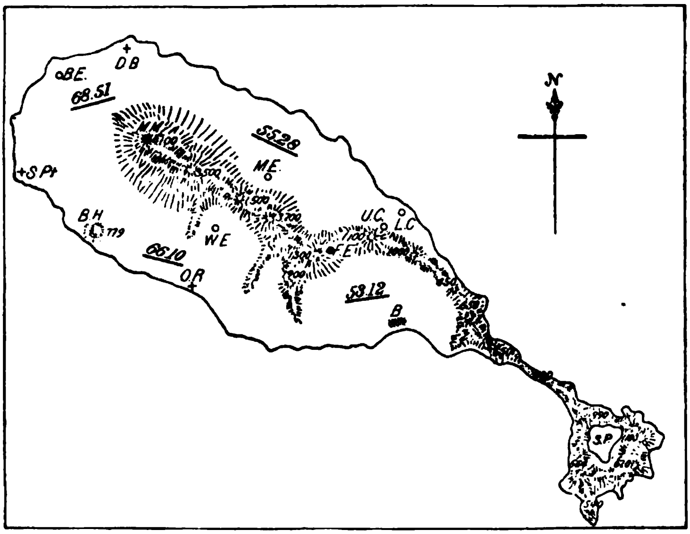

FIG. 7.—Island of St. Kitts, West Indies.

B., Basseterre, the capital and chief town, lat. 17° 18′ N., long. 62° 48′ W.; location of U. S. Weather Bureau station. O. R., Old Roads, a small village where it is said Columbus made a landing and which for a long time was the capital of the English part of the island. B. H., Brimstone Hill, at one time a celebrated fortress. S. Pt., Sandy Point, a small village. M. M., Mount Misery, an extinct volcano, about 4,100 feet high. S. P., Salt Pond. W. E., Wingfield Estate. M. E., Molyneux Estate. L. C., Lower Canada. U. C., Upper Canada. F. E., Fountain Estate. B. E., Brotherson Estate. D. B., Dieppe Bay, a small village.

The figures 66.10, etc., underlined, show the average annual rainfall in inches for the four regions of the island. The small figures, not underlined, show the altitudes of the corresponding locations, expressed in feet, above sea level.

1623.—On September 19 a hurricane destroyed the tobacco crop on the island of St. Christopher, this being the first crop planted and raised by the newly arrived colonists.—S. C., vol. 1, p. 252.

1625, September 19.—B. H.

1642.—During this year there were three hurricanes in the West Indies; the second lasted twenty-four hours, during which, at St. Kitts, 23 fully laden vessels were wrecked upon the coast, all the houses blown down, and the cotton and tobacco crops completely destroyed, and the salt ponds overflowed and rendered unproductive for some time.—S. C., vol. 1, p. 294.

1650.—No date.

1652.—No date.

1666.—August 4 and 5.

1667.—September 1, a tremendous hurricane devastated the island of St. Kitts; it began at 9 a. m. and lasted until 5 p. m. from the north, then shifting to the south, blew with such violence that all the houses and buildings were thrown down. The inhabitants sought shelter from its fury by throwing themselves upon the ground in the fields.

M. Laurent, the governor, in a letter to M. Colbert, says:

> There has blown here the most violent hurricane ever known, and I hold myself obliged to inform you that this island is in the most deplorable state that can be imagined, and that the inhabitants could not have suffered a greater loss, or been more unfortunate, except they had been taken by the English. There is not a house or sugar works standing, and they can not hope to make any sugar for fifteen months to come. As for the manioc, which is the bread of the country, there is not one left, and they are more than a year in growing. I can not describe to you, sir, the misery of this poor island without wounding my heart. It is as a place over which fire has passed. I assure you that if peace is not made, or men-of-war sent into this country to facilitate the bringing of cassava from the other islands, that the inhabitants and troops will die of famine. I shall do everything in my power to keep up the spirits of the inhabitants, who are stunned like men who are totally ruined, and I shall not spare either pains or trouble to maintain the island and remedy the evil, which is irremediable except succor arrive from without.—S.C., vol. 2, p. 78.

The hurricane of September 1, 1667, seems to have been the severest one in the history of St. Kitts.

1681.—The island of Antigua was desolated by a tremendous hurricane.

The following account of two hurricanes which occurred at St. Kitts in 1681 is from a letter written soon afterwards and published in the first volume of A Young Squire of the Seventeenth Century. It seems so quaint and interesting that its reproduction verbatim et literatim is justified in this connection.

> Saturday the 27th of August, about one or two in the morning, the winds blew very hard at northeast, which did small damage. Before day, the weather broke up with appearance of fair weather; but before nine of the clocke, it was overcast and proved a rayney, blustering day. About eight or nine o'clock at night the wind, veering more to the north and from the north to the northwest, increased till midnight; at which tyme it blew so vehemently hard, and so continued with small rayne and frequent lightnings, until within less than an hour of daybreake (when the storm began to cease), that I had not a house standing upon my plantation, in which I could shelter myself from the weather.
>
> It was a little after midnight, when a great part of the roof of my dwelling-house began to fly away; several of my out-houses being allready downe. Then I thought it tyme to shift for myselfe; which I did. Turning my people out before (who had been driven to my house by the insufficiency of their houses) I locked the door, and tooke the key in my pocket.
>
> I could not goe against the winde; and with no small difficulty could I goe with it, for fear of being driven away by it. At last we got (all but one of our company) to a little hut, which, we had agreed upon before, to make our rendezvous in; which sheltered vs from the violence of the storme, but not of the raine, the thatch being partly blown away. But to be wet was then no news to vs. Wee were in continual

feare oure little cottage should have beene blowne away; which rocked like a cradel. As soone as the storme began to cease, I went up to my house whiche I found miserably torne, and flat with the ground. My sugar-worke, in like manner, and all my buildings. I walked downe to my new sugar-worke, which I had built not long before, about a quarter of a mile or more from my house, towards the sea, to make my tenants' sugar canes; to whom I had leased fifty acres of land, and had newly begun to make sugar at it, and was then boiling at it, when the storme began. I found *that* likewise flatt with the grounde, the stone wall overturned, and the timber scattered in divers places farre distant from the house.

I must confesse, I did wonder more to see my house standing, than to see what was destroyed, considering the impetuosity of the weather. I had scarce time to view this losse, when the winde being shifted into the south, the storme began afresh. I made what diligence I could (the pathes beeing all spoyled), to get to the place where my dwelling-house did stand; to whiche the winde assisted me, being in my back, but veering to the southeast.

It blew a frett of winde, and continued with suche violence for severall hours, that it did much more damage in some partes of the island than the fore-part of the storme. But it was not comparable to the former with vs. I stoode for shelter behinde that part of the wall of my house, which was left standing, till I feared it would fall upon me, and then shifted to another shelter, little better than the former.

About ten or eleven of the clocke, the winde ceased; but most part of the day was wet and rayney, very uncomfortable for those that had neither victuals to eat, dry cloathes to put on, or a house to shelter in, or fire to dry themselves by—which was the condition of most people. It was a deplorable sight to see the spoyle that was done in the canes and provisions, in comparison of which the losse of all our houses and workes is as nothing.

That day, although Sunday, I got up a little house, in whiche to secure myselfe and the best of my goods from the wet; and I used all diligence to gett up a couple of rooms, and one of my sugar-workes, and to put some Indian provisions in the ground, having thirty-two negroes, besides whites to feed every day (for which I blesse God). I was now indifferently well at my ease for the present; my two rooms being built, and everything indifferently well in order, towards the repaireing of my buildings and my other losses. When on Tuesday, the fourthe of October, after a very tempestuous night, about breake of day, a second hurricane began, which lasted until two or three in the afternoone. I used all the endeavours I could to secure my new house, where I was lodged. But all my endeavours were not sufficient, but that, about ten or eleven of the clocke, the roof was blown away over our heads all at once and carried many yardes from the house—and *that* in a very instant of time. But I thank God none of vs were hurt, but one who had a small hurt with a nayle in a board.

I made what haste I could out, and passed the remainder of the storme at the side of a wall, which afforded me some small shelter. This and the other hurricane were more fierce here and in another quarter, than in any other part of the island, as appeared by the effects of them. The damages done by this second storme, were very great, and would have been much more, had not the great spoyle wrought by the former hurricane deprived it of matter to worke upon. Though this was not so tedious, or exceedingly fierce as that, yet it hath destroyed our provisions, and hath occasioned a sickly and scarce time amongst vs. It was not violent at Antegoa, where several ships were cast on shoar.

1733, June.—B. H.

1737, September 9.—B. H.

1747.—There were two violent hurricanes this year, one on September 21 and the other on October 24. They did great damage among the Leeward Islands. Fourteen sail were lost at St. Kitts and 36 at the other islands.—S. C., Vol. 2, p. 305.

1765, September.—B. H.

1766.—This year seems to have been marked by an unusual number of direful calamities in the West Indies. An earthquake at Santiago de Cuba killed 40 persons, and at Grenada the same or another threw down the sugar works and hills in several places, so that it was impossible to ride round the island on horseback.

At 10 p. m. of August 13 a strong northwest gale set in at Martinique, and about midnight the shock of an earthquake added to the horrors of the increased hurricane. At 3 a. m. the storm abated, and daylight revealed a scene of desolation and woe; wrecks and dead bodies covered the shore at St. Pierre; the streets were covered with ruins, while the roads were blocked by trees uprooted by the storm and enormous stones brought down by the rivers. At 5 a. m. a waterspout burst upon Mount Peleus, overwhelming the neighboring plains. By 6 o'clock it was quite calm and the sea was smooth. As many as 90 persons are said to have perished, many of these under the ruins of their own houses, while twice that number were wounded. Seven English and 28 French vessels were wrecked; also 12 passage canoes.

On the 13th, 14th, and 15th of September such violent gales raged at St. Kitts and Montserrat that 13 vessels were wrecked at the former and all at the latter. At Montserrat half the town was destroyed and upward of 200 persons reduced to distress by the torrent from the mountains.

St. Eustatius suffered severely from a hurricane on September 21; the provision grounds and cane plantations were destroyed; several vessels lost. The salt works at Tortuga were destroyed by the hurricane, also, and 3 French and 5 Newfoundland vessels driven on shore.

On the 6th of October 5 vessels were driven on shore at Dominica in a gale of wind, and upward of 50 sail at Guadeloupe.

On the 22d and 23d of October a violent hurricane did considerable damage in the harbor of Pensacola. The Spanish fleet from Vera Cruz for Havana and old Spain, consisting of 5 large ships of register richly laden, were driven ashore at the Bay of St. Bernard.—S. C., vol. 2, p. 390.

1772.—During the last days of August and the first days of September a hurricane passed over the West Indies, causing frightful havoc among the Leeward Islands. At Dominica 18 vessels were driven ashore and lost. Several war ships were driven ashore at Antigua. At Montserrat and Nevis nearly every house was blown down. The hurricane passed over St. Kitts on August 31, beginning at daylight. At noon the storm abated to such an extent that the people thought that it was over, but the wind suddenly shifted from the northeast to the southwest by south, and blew with increased violence, destroying almost every house, sugar mill, tree, and plant, killing several and wounding many persons. The damage was estimated at £500,000 sterling. At St. Eustatius 400 houses were destroyed or rendered untenable, and the Dutch church blown into the sea. At Saba 180 houses were blown down. At St. Martins nearly all the houses and all the plantations were destroyed. The disastrous effects of this storm were felt nowhere more forcibly than at Santa Cruz, where, it is said, the sea rose 72 feet above its usual height, carrying every ship at the island on shore, some as far as 100 yards inland. Large stones were brought down from the mountains, and there was a terrific electrical display. Four hundred and sixty houses were thrown down at Christianstadt and all but three at Fredericstadt. The magazines and stores were quite ruined. The total damage was estimated at $5,000,000. The damage at St. Thomas was placed at $200,000.—S. C., vol. 2, p. 411.

1772, November 22.—B. H., p. 23.

1775, October 16.—B. H., p. 23.

1776, September 5 to 6.—B. H., p. 23.

1780, August 25.—The devastations of this hurricane were so general that it is deemed best to reserve an account of the same for Chapter VIII, which see.

1785, August 25.—Great damage to shipping on account of severe hurricane.—Notes.

1792, July 14.—In consequence of a southerly gale, a ship with 500 hogsheads of sugar was driven on shore and dashed to pieces.—Notes.

1792, August 2.—A tremendous gale made almost general havoc among the shipping, the loss being universal, not only in property, but in lives.—Notes.

St. Kitts experienced a terrific flood, which caused the loss of many lives and the destruction of much property.—S. C., vol. 3, p. 62.

1793, August 12.—About 30 vessels were lost or stranded by a hurricane at St. Kitts.—S. C., vol. 3, p. 71.

1803, October 12.—Two American vessels were stranded by a southerly swell.—Notes.

1804, September 3.—Thirteen vessels were wrecked by a hurricane at St. Kitts. Among them was the *Aurora*, with cargo valued at 46,000 pounds sterling.—S. C., vol. 3, p. 307.

1806, October 28.—A southerly gale, accompanied by an awful thunderstorm, destroyed six small vessels.—Notes.

1807, July 25.—A southerly gale drove several vessels on shore, among them the ship *Maria*, with upward of 500 hogsheads of sugar, nearly all of which was lost.—Notes.

1813, July 22-23.—Two ships, four brigs, five schooners, and four sloops were driven on shore at night and stranded. Two seamen were drowned.—Notes; see also S. C., vol. 3, p. 521.

1815, July 25.—B. H., p. 24.

1816, September 15.—In consequence of an easterly gale all vessels put to sea. One sloop lost in the channel between this island and St. Eustatius; captain and two of the crew drowned.—Notes.

1817, September 8.—A strong southerly gale drove a sloop ashore.—Notes.

1818, September 22.—Strong westerly winds; no damage to shipping; one seaman drowned.—Notes.

1819, September 21–23.—A hurricane swept over the Leeward Islands, the Virgin Islands, and the Bahamas. It was first noticed near St. Lucia, passed over or near Antigua, St. Kitts, St. Bartholomews, and St. Martins. It was most destructive in the Virgin Islands. At St. Kitts it did considerable damage to the estates' works.—W. J. B.

1820, August 28.—Heavy winds from the south and west; ship *Pitt* ran ashore.—Notes.

1821, September 9.—A devastating hurricane from the southeast unroofed or seriously damaged dwelling houses, estates' works, and other buildings from one end of the island to the other. Canes were thrown flat and provisions destroyed. Many of the officers' quarters on Brimstone Hill were injured and buildings of minor importance shattered.—Notes.

1824, September 7.—A northeasterly gale drove two sloops aground. No damage on land.—Notes.

1825, July 26.—An east-southeast gale stranded one brig, one schooner, and three sloops. Four seamen were drowned. This storm was very severe at Guadeloupe, where the barometer fell 1.86 inches.—W. J. B.

1827, August 17.—A destructive hurricane, thought to be equal in violence to the "great hurricane" of 1772; houses in the town thrown down, dwellings and works seriously injured; tamarind and other trees which had withstood the ravages of time were torn up by the roots; several small vessels lost. A solemn fast and humiliation observed on the 31st.—Notes.

1829, October 30.—Southerly gale; five small vessels driven on shore; no damage on land.—Notes.

1830, August 12.—A slight blow; fences and trees thrown down; two sloops driven ashore.—Notes.

1831, August 11.—Heavy swell and southerly wind; five small vessels wrecked; two lives lost.—Notes.

1833, August 14.—Southerly wind and heavy sea; two or three small vessels driven on shore; no damage on land.—Notes.

1835, August 12.—Severest hurricane experienced for years; few premises escaped without some injury either in the dwellings, outbuildings, or fences; a few small houses in Basseterre destroyed; great loss of cattle; canes laid prostrate, and provision grounds dreadfully cut up; several deaths took place from bruises received from falling timber. The damage sustained by the different barracks and buildings on Brimstone Hill was estimated at £3,000 sterling. Total loss from returns furnished by the vestries of the several parishes estimated at £80.000 sterling. At Antigua the barometer fell 1.4 inches at the rate of 1 inch in one hour and twenty-seven minutes.—W. J. B. and Notes.

1837, August 2.—A heavy wind from northwest shifting to the west threw a tremendous sea into the harbor. Two ships, 1 schooner, and 2 sloops driven on shore and wrecked; 1 seaman drowned. Not much damage on shore.—Notes.

1838, November 13 (or 15).—Southerly wind, heavy swell, 2 sloops driven on shore.

1848, September 19.—B. H.

1851, July 10.—B. H.

1851, August 16.—B. H.

1852, September 22.—B. H.

1859, September 2.—The center of a rather mild hurricane passed over St. Kitts. A numer of boats were wrecked besides other damage. It passed over St. Croix also.—W. J. B.

1871, August 21.—This was a very severe and destructive hurricane. The center passed over the island. The barometer began to show a downward tendency about 1 p. m. of the 20th, and by 1 a. m. of the 21st the fall became very decided, the wind being from the east-northeast. By 6 a. m. the barometer had fallen to 29.60, and the wind had shifted to the north; at 8.40 the barometer stood at 28.50 and there was a calm lasting twenty-two minutes, after which the wind came from the southwest and the barometer began to rise. The damage done was quite general. The center of this storm passed over Antigua and Statia (St. Eustatius?) also.—W. J. B.

The following memoranda relative to this storm are taken from a private meteorological journal kept by Mr. George James Evelyn, of Basseterre, and were made at the time of the hurricane, viz:

Date.	Hour.	Barometer.	Wind.	Remarks.
21st August, 1871	1.00 a. m.	29.80	ENE.	Squalls and short showers.
	3.00	29.74	ENE.	
	4.00	29.70	ENE.	Very strong wind.
	6.00	29.60	N.	Stormy.
	7.00	29.50	N.	Very heavy.
	7.30	29.40	N.	Tempest.
	8.00	29.27	N.	
	8.15	29.20	N.	Hurricane.
	8.20	29.10	N.	
	8.25	29.00	NW.	
	8.28	28.90	NW.	
	8.40	28.50	NW.	Dreadful.
	8.50	28.50	....	A calm for 22 minutes.
	9.12	29.10	SW.	
	9.40	29.30	SW.	Good breeze and heavy sea.
	9.50	29.40	SW.	Strong.
	10.20	29.50	SW.	Very heavy sea.

1876, September 12.—The center of this hurricane passed to the north of St. Kitts, but made itself very severely felt thereat. The following notes are taken from Mr. Evelyn's journal:

Date.	Hour.	Barometer.	Wind.	Remarks.
11th	10.00 a.m.	30.03	E.	Good breeze; clear and fine; very hot.
	4.00 p.m.	30.00	E. and ENE.	Good breeze; clear and fine; splendid.
12th	10.00 a.m.	29.97	NE.	Strong breeze; threatening.
	4.00 p.m.	29.85	NE.	Very strong breeze; squally; bad.
	7.00	29.66	NW.	Do.
	7.36	29.57	NW.	Do.
	7.40	29.54	NW.	Very strong breeze; very heavy.
	7.45	29.50	NW.	Do.
	8.00	29.48	WNW.	Very strong breeze; very bad.
	8.45	29.35	WNW.	Wind changing to west; very heavy.
	9.30	29.40	WSW.	Very strong wind; heavy sea.
	9.45	29.46	WSW.	Do.
	10.30	29.60	WSW.	Do.
13th	12.30 a.m.	29.85	WSW.	Wind abating and less sea.
	2.00	29.90	SW.	Do.
	7.00	29.98	ESE.	Clear sky; good breeze; heavy sea; no thunder during storm; lightning in NW. and WSW. at intervals.

1880, January 12.—This date is historic because of the occurrence of a most disastrous flood at St. Kitts. There stands in the cemetery at St. Kitts a plain massive monument with the following inscription, viz: "Sacred to the memory of those who perished in the flood in Basseterre, St. Christopher, on the 12th of January, 1880, and commemorative of that awful visitation, in which 231 persons lost their lives, of whom 101 are buried here." From eyewitnesses I learned a few additional facts and details concerning this event.

It appears that there were no premonitory signs of the impending disaster further than that toward sunset an unusual warmth was felt which continued up to 9 o'clock, when an "intense cold set in, followed by a light shower of rain." The clouds gathered early in the evening, quickly enshrouding the city in intense darkness: "The darkness could almost be felt." Occasional flashes of lightning, accompanied by "deep rumbling thunder," now and then relieved the painful feeling. About 11 o'clock the rain began again and, it is said, it looked as if sheets of water were pouring out of the clouds. Soon the place was flooded, and ere long the water began to creep into the houses, to the great consternation of the inmates, who, upon attempting to escape, found the streets like rivers, making egress not only unsafe but well-nigh impossible. Those who were so fortunate as to possess an upstairs availed themselves of the security afforded by a more elevated position, but unfortunately the bulk of the people lived then as now, in small one-story, one-roomed huts built of light material and loosely put together, so that houses and all soon began to move seaward. The rain continued for about three and a half hours, resulting, as above stated, in the drowning of 231 persons, perhaps more, and the loss of much property. Many persons were buried beneath a layer of mud several feet deep, brought down by the waters from the hillsides and neighboring estates.

Of course, all gauges and marks by which the amount of the precipitation could be measured were either swept away or entirely submerged, and only individual opinions can now be had on this point. I find this note in Mr. George James Evelyn's journal, viz:

> It is supposed that 36 inches fell during the time from 12 o'clock (midnight) to 3 a. m., 13th. Town flooded; immense damage to houses; many persons lost and missing.

There are some who estimate the fall as low as 23 inches. It was this heavy fall in the town, augmented by the overflowing of the mountain streams, which caused this great havoc in the city of Basseterre.

1881, August 21.—This hurricane did very little damage in St. Kitts.

1889, September 2.—In regard to this hurricane as it affected St. Kitts, Dr. W. J. Branch writes me as follows, viz:

> I was in Scotland when the hurricane of September 2, 1889, occurred. Mr. Cable tells me that it was first reported from Dominica, and that it struck St. Croix after leaving St. Kitts. It blew the steamship *Roraima* ashore. I found her on the rocks at Rawlins when I came home in November. From the account given to me, there is no doubt that the hurricane center passed over St. Kitts, for there was a distinct calm in the middle of it of twenty or more minutes' duration, but it seems to have been a mild specimen of the cyclone genus.

1898, September 12.—The hurricane passed the island with only a slight brush, doing no damage.—Monthly Weather Review, September, 1898, p. 394.

1899, August 7.—The day preceding the hurricane was the warmest of the season thus far, the temperature reaching a maximum of 88°, and the afternoon was characterized by gusty, whirling winds from the northeast, with an occasional momentary calm, and by a hazy atmosphere, with strato-cumulus clouds moving from the east rather rapidly and above which there seemed to be a thin sheet of cirro-stratus, through which the sun shone with a pale, sickly light. The sea was wonderfully clear, so much so that one could see very distinctly the stones on the bottom, but gave no sign of unusual agitation. The sunset was not marked by saffron skies, nor did the barometer, up to this time, show the slightest tendency to depart from its normal condition. At 3.30 p. m the wind set in steadily from the northeast at the rate of 12 miles per hour, with a gradually increasing force. At 10 p. m. the barometer began to fall, and the wind, still increasing in force, had attained a velocity of 18 miles per hour. By 3 a. m. of the 7th the barometer dropped 0.01 inch, and the wind was blowing at the rate of 24 miles per hour, and there was an apparent tendency to cloudiness, so that by 5.30 a. m. the sky was almost entirely overcast with low clouds, from which frequent showers fell.

The storm came from the southeast and moved toward the northwest, the center passing a little south of the island. The barometer reached its lowest reading at 5 p. m., seventy-fifth meridian time, when it stood at 29.268 inches. After this hour it began to rise rather gradually.

The wind continued from the northeast until about 6 p. m., when it veered to the east, where it remained until about 8 p. m.; it then changed to the southeast, and so continued to the end of the storm. The verifying velocity (45 miles per hour) began at 2.34 p. m. and ended at 12.25 a. m. of the 8th; the storm therefore lasting nine hours and fifty-one minutes. The maximum velocity (the greatest velocity for any five minutes) was 72 miles per hour, and occurred between 4.22 and 4.27 p. m. The extreme velocity (1 mile in the shortest time) occurred at 4.40 p. m., when the wind blew a mile in one-half minute, or at the rate of 120 miles per hour. The total wind movement during the storm was 478 miles, as follows, viz: From the northeast, 196; from the east, 112, and from the southeast, 170. The hurricane was accompanied by a light rain, the total amount of which was 1.28 inches. The heaviest fall occurred between 4.53 p. m. and 5.10 p.m. There was neither thunder nor lightning during the storm.

So far as known there was no loss of life at St. Kitts, but the property loss was considerable. A number of very substantial buildings were blown down, many huts entirely destroyed, and the canes badly damaged.

(For fuller details see Monthly Weather Review for August, 1899, p. 345.)

1899, September 8.—This hurricane, as compared with that of August 7, was slightly less intense, and far less disastrous, owing, no doubt, to the fact that only the strong trees and buildings were left, and these were able to resist successfully the attacks of the feebler storm.

The hurricane began at 3.40 p. m. and ended at 2.25 a. m. of the 9th, lasting, therefore, ten hours and forty-five minutes, during which time there was a total wind movement of 514 miles, or an average of 48 miles per hour during the entire storm. The maximum velocity of the wind was 62 miles, and occurred between 8.18 and 8.23 p. m. The extreme velocity was 120 miles per hour, at 5.51 p. m.

The lowest reading of the barometer, 29.506, occurred at 5 p. m., and the wind came from the southwest during the entire storm. The total rainfall was 3.13 inches, the heavest fall being during the first two hours of the storm.

A few small huts were destroyed, rendering about 200 people homeless; two schooners with cargoes, total value $25,000, were wrecked; one small boat, valued at $240, wrecked. The cane crop suffered the greatest injury because of the fact that the storm of August 7 blew the canes from the northeast and this one from the southwest, thus almost twisting them out of the ground.

CHAPTER VIII.

BRIEF HISTORICAL NOTES ON REMARKABLE WEST INDIAN HURRICANES AND EARTHQUAKES.

We present in this chapter some notes relative to events occurring in the West Indies since their discovery. Much more might be said of the storms of recent years, but full and accurate accounts of these are accessible to almost everyone, hence a reproduction of these is unnecessary. The authority for each note is given (the abbreviations are the same as for the preceding lists). Many of these notes have also been published in Bulletin H of the Weather Bureau.

1492.—While coasting along the north coast of Cuba Columbus was driven by violent gales 56 leagues to the northeast. He was also compelled to remain in harbor off Espanola some days because of "stress of weather."—S. C., vol. 1, p. 12.

1493.—On returning to Spain Columbus and his fleet were overtaken by a severe storm on February 12, which lasted three days and threatened them with certain destruction, so much so that Columbus wrote an account of his discoveries and threw it overboard.—S. C., vol. 1, p. 17.

1494.—While on his second voyage Columbus anchored at Cape Santa Cruz, and while there, "upon the 16th July a violent hurricane occasioned the admiral to declare that nothing but the service of God and the extension of the monarchy should induce him to expose himself to such dangers."—S. C., vol. 1, p. 35.

1498.—When 480 miles southwest of the Cape Verde Islands, Columbus found that "the altitude of the north star was five degrees." Here, in a calm, he expected that the heat would set the vessels on fire; the men were alarmed and dared not go below, though the stores were spoiling. This weather lasted eight days; the first only was clear, the seven following it rained; had all been as hot as the first, Columbus says nothing could have saved them.—S. C., vol. 1, p. 51.

1502.—While searching for a passage to the South Sea Columbus arrived off Santo Domingo and asked permission to enter the harbor which was refused. His object in entering the harbor was to exchange his vessel and to find shelter from a hurricane which Columbus thought was approaching. The fleet sailed July 1 and within twenty-four hours twenty sail with all on board perished. Columbus said: "The gale was terrible, and in that night my vessel parted company, every one expecting death, and each considering it certain that the others were lost. With the exception of Job there never was a man who would not have died in despair: When to save my life and that of my son, brother, and friends, I was at such a time forbidden the harbors, which, by God's permission, I had gained for Spain, sweating blood. The vessel in which I was, weathered the gale marvelously; it pleased God that she received no damage whatever. My brother was in the unsafe vessel, and, next to God, was the means of saving her. In this gale we made Jamaica."—S. C., vol. 1, p. 76.

1508.—On the 3d of August all the thatched houses in Santo Domingo, and several of those built with stone, every house in Bonaventura, and twenty sail of vessels, were destroyed by a hurricane. At first the gale blew from the north, then shifted suddenly to the south.—S. C., vol. 1, p. 107.

1509.—On July 10, Admiral Don Diego Columbus arrived at Santo Domingo with his bride, and a few days later almost the entire city was destroyed by a hurricane. These visitations were considered marks of divine displeasure.—S. C., vol. 1, p. 109.

1526.—In October a violent hurricane did great damage in the island of Española; rivers overflowed their banks. No such had been experienced in that island for many years.—S. C., vol. 1, p. 156.

1530.—There was great distress among the inhabitants of San Juan because of a hurricane, which was followed by rainstorms, so that the rivers were overflowed, crops, trees, and herds were washed away; the works at the gold mines and other undertakings were suspended.—S. C., vol. 1, p. 167.

1591.—On July 17 a fleet of 77 sail left Havana for Spain, and on August 10, in latitude 35° north they were overtaken by a gale and the commander of the fleet with 500 men perished. Three or four days later, in another gale, five or six of the largest ships with all their crews and the vice-admiral were lost. About the end of August, in latitude 38°, they experienced another gale during which 22 sail perished. September 6 the remaining 48 arrived within sight of Flores, where they were separated by another gale, so that of the 123 sail that were expected in Spain this year from the West Indies but 25 arrived.—S. C., vol. 1, p. 212.

1635.—Du Pont, while on his way from Martinique to St. Kitts to bear the news of a treaty of peace between himself and the Caribs to D'Enambuc, was driven by a violent gale to the coast of Española, where he was taken prisoner by the Spaniards and closely confined for three years.—S. C., vol. 1, p. 275.

1656.—The island of Guadeloupe was desolated by a fearful hurricane. Most of the houses were destroyed, all the domestic animals were killed, and all the plantations laid waste. Every vessel at anchor in the roads was wrecked and most of their crews drowned.—S. C., vol. 2, p. 14.

1664.—The crop of potatoes was destroyed by a violent hurricane at Guadeloupe. An earthquake at St. Kitts did considerable damage.—S. C., vol. 2, p. 53.

1666.—On August 4 a hurricane began at Guadelqupe at 6 p. m., the wind blowing from the north. It continued with great violence until midnight, when there was a calm of a quarter of an hour, the wind then shifting to the south and driving everything before it with irresistible force. Every vessel and boat on the coast of Guadeloupe was dashed to pieces—all the vessels in the Saints were driven on shore—and of Lord Willoughby's fleet (consisting of 17 sail with 2,000 troops) only two were ever heard of afterwards. An armée en flute of 22 guns got to Montserrat with only the stump of her mizzenmast standing, and a fire ship got to Antigua dismasted. The bottom of one ship was washed on shore at Cabsterre, Guadeloupe, and another at the Saints. The whole coast was covered with wrecks of masts and yards. A figure from the stern of Lord Willoughby's ship was recognized among the ruins. The hurricane lasted twenty-four hours; houses and trees were blown down, and a great number of cattle killed. The sea rose and was driven to an unusual height. All the batteries—walls of 6 feet thickness—near the sea were destroyed and guns—14-pounders—were washed away. The storm was felt at St. Christopher and Martinique, but with less violence.—S. C., vol. 2, p. 70.

1674.—At Barbados, on the 10th of August, a hurricane blew down 300 houses, killing 200 persons; wrecked eight ships in the harbor, and so damaged the plantations that very little sugar was made the two succeeding years.—S. C., vol. 2, p. 110.

1675.—The island of Barbados was again devastated by a hurricane in August of this year. The crops were destroyed, and the people asked the British Government to relieve them of an impost of 4½ per cent on exports. This was refused.—S. C., vol. 2, p. 111.

1681.—The island of Antigua was desolated by a tremendous hurricane.—S. C., vol. 2, p. 121.

1689.—A dreadful mortality swept away one-half the inhabitants of Nevis.—S. C., vol. 2, pp. 146, 149.

1690.—The island of Antigua was almost desolated by an earthquake.—S. C., vol. 2, p. 158.

1692.—Jamaica suffered from a dreadful earthquake on June 7, between 11 and 12 o'clock noon. The town of Port Royal was almost completely destroyed in less than three minutes. About 3,000 of the inhabitants with their houses found one common grave. The sinking of the wharfs was but a prelude to that of the town; those nearest the water first disappeared; the next in succession followed. In the meanwhile the streets began to gape, "opening those dreadful fissures into which the miserable remnant of the inhabitants fell who had escaped the previous ruin and were fleeing for shelter in the open air." The water began to roll where the town had flourished, and swept from sight the devastations which the earthquake had made. Several of the inhabitants were swallowed up and returned again to the surface of the earth through distant apertures which had no visible connection with those which first yawned to receive them. Some were returned alive and even without material injury. The waters rose and filled the houses which had survived the shock, to the upper story—"a preternatural tide that was to ebb no more." Some of the streets were laid several fathoms deep under water; the harbor was agitated as in a storm. The ships parted their cables. The *Swan* frigate lay by the wharf, and was forced over the tops of the sunken houses, and saved some hundreds of the inhabitants. The fort and about two hundred houses escaped; but part of the neck of land, about a quarter of a mile in length, was entirely submerged, with all the houses, which stood very thick upon it.

A general sickness ensued, which, with the other miseries, left the island almost destitute. The assembly ordered a perpetual anniversary fast in commemoration of this calamity.—S. C., vol. 2, p. 161.

1722.—The town of Port Royal, Jamaica, was visited by a severe hurricane on the 28th of August, in which 26 merchant vessels were wrecked and 400 persons killed. An eyewitness says:

> The hurricane began at 8 in the morning, two days before the change of the moon. It gave at least forty-eight hours, notice by a noisy breaking of the waves upon the keys, very disproportioned to the breeze, a continued swell without reflux of the water, and the two nights preceding, prodigious lightning and thunder, which all the old, experienced men foretold would be a hurricane, or that one had already happened at no great distance. The wind began in flurries from the northeast and flew quickly round to the southeast and south-southeast, where it continued, the stress of the storm, bringing such quantities of water that our little island was overflowed 4 feet at least; so that with the fierce driving of shingles about our ears, and the water floating boats, empty hogsheads, and lumber about the streets, those without doors were every moment in danger of being knocked on the head or carried away by the stream. Within it was worse, for the waters sapping the foundations, gave continual and just apprehension of the houses falling, as in effect half of them did, and buried their inhabitants. * * * The whole rise of the water was computed at 16 or 18 feet at a place where it is not ordinarily observed to flow above 1 or 2. At 5 in the evening the waters abated, and so quickly as to leave the streets dry before 6. * * * Wrecks and drowned men were everywhere seen along shore; general complaints of loss at land, which made it a melancholy scene; and to finish the misfortune, the slackness of the sea breeze, calms, lightning, stagnating waters, broods of insects thence, and a shock or two of earthquake that succeeded the hurricane combined to spread a baneful influence, and brought on a contagion fatal for some months through the island.

B. Edwards says that as upon the same day of the month ten years before another hurricane had shaken the island, the anniversary of the day was, by an act of the assembly, set apart for fasting and humiliation.—S. C., vol. 2, p. 223.

1737.—On September 9 the town of St. Louis, St. Domingo, was destroyed by a hurricane. All the sugar cane and cotton trees were destroyed and all the ships in the harbor were thrown upon the coast. This hurricane did great damage at St. Kitts and Montserrat. At the latter island it blew down all the windmills and houses and carried away mules, negroes, and cattle into the sea. The sugar canes were all destroyed.—S. C., vol. 2, p. 264.

1744.—On the 20th of October, at Jamaica, a dreadful hurricane began at 6 p. m. and lasted until 6 the next morning; the wind was all that time due south. Mosquito fort was demolished. Eight English ships and vessels and 96 merchant vessels were stranded and foundered. Out of 105 vessels only one, the *Ripon*, rode out the gale and she without masts. One hundred and eighty-two men were drowned.—S. C., vol. 2, p. 301.

1754.—A hurricane in September did great damage at St. Domingo to the sugar and indigo plantations. Twelve ships were driven ashore and 1,700 hogsheads of sugar lost.—S. C., vol. 2, p. 317.

1759.—"In the month of September a heavy gale of wind from the northeast so greatly impeded the current of the Gulf stream that the water forced at the same time into the Gulf of Mexico by the trade winds rose to such a height that not only the Tortugas and other islands disappeared, but the highest trees were covered on the peninsula of Larga; and at this time (so says Wm. Gerard de Brahm esq.), the snow,[a] *Litbury*, John Lorrain, master, being caught in the gale, came to an anchor, as the master supposed, in Hawke Channel; but to his great surprise found his vessel the next day high and dry on Elliotts Island, and his anchor suspended in the boughs of a tree."—S. C., vol. 2, p. 336.

1761.—On the 31st of March, at 4 p. m., the sea at Barbados began to flow; at 8 it appeared to ebb; but at 10 it increased considerably and continued so until 6 the next morning. A similar agitation in the water was observed there at the time of the earthquake at Lisbon in 1755.—S. C. vol., 2, p. 343.

1762.—A storm from the southward followed by an earthquake destroyed a great part of the walls surrounding the town of Carthagena on December 9; wrecked many houses, among them the castle of Santa Maria; drove two Spanish men-of-war on shore.—S. C., vol. 2, p. 345.

1768.—On the 25th of October a brief but violent hurricane occurred at Havana. The storm began from the south and died away from the north, having continued not more than two hours; nevertheless, in that short time, 98 public buildings and 4,048 houses were destroyed, and above 1,000 persons killed almost instantly.

It was this year that the snow[a] *Rodney*, carrying convicts to Maryland, was forced by stress of weather into Antigua. It is also stated that there was great distress among the convicts, as many as 11 died from want, and the survivors had to eat their shoes and the like to sustain life.—S. C., vol. 2, p. 398.

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[a] A two-masted square-rigged vessel.

1770.—On the 3d of June, in the afternoon, the island of St. Domingo suffered from a fearful earthquake. The city of Port au Prince was entirely destroyed; not one house was left standing, and more than 500 people were buried beneath the ruins. La Croix de Bouquet, a small town, with the greater part of the inhabitants, was swallowed up. The sea rose a league and a half in the island.—S. C., vol. 2, p. 407.

1771.—The great calamity of this year came in the form of a famine at the Bay of Honduras, caused, it is said, by locusts. They ate up every green thing, and in some places covered the ground a foot thick. It was estimated that as many as 80,000 Indians died from starvation because of this awful visitation.—S. C., vol. 2, p. 408.

1779.—This year was marked by a drought and famine at Antigua. The water supply became quite insufficient and the stock and negroes perished in the greatest agony. A malignant fever raged at the same time, threatening all with death. Mr. Baxter, a Methodist preacher, appointed the 28th day of May as a day of fasting, and he says: "It is remarkable that while we were assembled for prayer the Lord granted our request by sending an abundance of rain."—S. C., vol. 2, p. 459.

1780.—The following data relative to the great hurricane of this year are taken from Southey's Chronology, pages 467 to 476.

The hurricane began at Barbados on the morning of the 10th of October, and continued with little intermission about forty-eight hours. In the afternoon of the first day all the ships were driven from their anchors to sea. In the course of the night Bridgetown was nearly laid level with the earth. Daylight presented a scene of desolation seldom equalled; not one house or building in the island, however strong or sheltered, was exempt from damage. Most of the live stock and 4,326 persons perished; the loss which the colony sustained was estimated at 1,320,564 pounds sterling. Upon the authority of a public document sent to the secretary of state by the governor of the island, it is said that a 12-pound gun was by the wind and waves carried from the south to the north battery, a distance of 140 yards. Some Spanish prisoners, under Don Pedro St. Jago, assisted the troops in relieving the inhabitants and preventing the negroes from plundering.

Parliament voted 80,000 pounds sterling for the relief of the sufferers.

Major-General Cunninghame, governor of Barbados, sent the following account of the hurricane at that island to the secretary of state and Major-General Vaughan. The commander in chief refers the English Government to that account for a description of it:

"*Copy of a journal of what passed at Barbados, from the 9th of October until the 16th.*

"The evening preceding the hurricane, the 9th of October, was remarkably calm, but the sky surprisingly red and fiery; during the night much rain fell. On the morning of the 10th much rain and wind from the NW. By 10 o'clock it increased very much; by 1 the ships in the bay drove; by 4 o'clock the *Albemarle* frigate (the only man-of-war here) parted her anchors and went to sea, as did all the other vessels, about twenty-five in number. Soon after, by 6 o'clock, the wind had torn up and blown many trees, and foreboded a most violent tempest. At the Government house every precaution was taken against what might happen; the doors and windows were barricaded up, but it availed little. By 10 o'clock the wind forced itself a passage through the house from the NNW., and, the tempest increasing every minute, the family took to the center of the building, imagining, from the prodigious strength of the walls—they being 3 feet thick—and from its circular, it would have withstood the wind's utmost rage; however, by half past 11 o'clock they were obliged to retreat to the cellar, the wind having forced its way into every part, and torn off most of the roof. From this asylum they were soon driven out, the water being stopped in its passage, and having found itself a course into the cellar, they knew not where to go; the water rose 4 feet, and the ruins were falling from all quarters. To continue in the cellar was impossible; to return to the house equally so; the only chance left was making for the fields, which at that time appeared equally dangerous; it was, however, attempted, and the family were so fortunate as to get to the ruins of the foundation of the flagstaff, which soon after giving way, every one endeavored to find a retreat for himself. The governor and the few who remained were thrown down, and it was with great difficulty they gained a cannon, under the carriage of which they took shelter. Their situation here was highly deplorable; many of the cannon were moved, and they had reason to fear that under which they sat might be dismounted and crush them by its fall, or that some of the ruins that were flying about would put an end to their existence; and to render the scene still more dreadful they had much to fear from the powder magazine, near which they were. The armory was level with the ground and the arms, etc., scattered about.

"Anxiously did they wait the break of day, flattering themselves that with the light they would see a cessation of the storm; yet when it appeared little was the tempest abated, and the day served but to exhibit the most melancholy prospect imaginable. Nothing can compare with the terrible devastation that presented itself on all sides—not a building standing; the trees, if not torn up by the roots, deprived of their leaves and branches, and the most luxuriant spring changed in this one night to the dreariest winter. In vain was it to look around for shelter. Houses that, from their situation it was to have been imagined would have been in a degree protected, were all flat with the earth, and the miserable owners, if they were so fortunate as to escape with their lives, were left without a covering for themselves and family. General Vaughan was early obliged to evacuate his house. In escaping he was much bruised. His secretary was so unfortunate as to break his thigh.

"Nothing has ever happened that has caused such universal desolation. No one house in the island is exempt from danger. Very few buildings are left standing on the estates. The depopulation of the negroes and cattle, particularly of the horned kind, is very great, which must, more especially in these times, be a cause of great distress to the planters. It is as yet impossible to make any accurate calculation of the number of souls who have perished in this dreadful calamity—whites and blacks together, it is imagined to exceed some thousands; but fortunately few people of consequence are among the number. Many are buried in the ruins of the houses and buildings, many fell victims to the violence of the storm and inclemency of the weather, and great numbers were driven into the sea and there perished. The troops have suffered inconsiderably, though both the barracks and the hospital were early blown down. Alarming consequences were dreaded from the number of dead bodies that lay uninterred, and from the quantity the sea threw up, which, however, are happily subsided. What few public buildings there were are fallen in the general wreck. The fortifications have suffered very considerably. The buildings were all demolished, for so violent was the storm here, when assisted by the sea, that a 12-pounder gun was carried from the south to the north battery, a distance of 140 yards. The loss to this country is immense. Many years will be required to retrieve it."

The hurricane nearly ruined the Spanish fleet under the command of Don Bernardo de Galvez. Four capital ships, besides others of different denominations, were totally lost, and all on board, above 2,000 persons, perished. The remainder of the shattered fleet got to the Havana.

At St. Lucia only two houses were left standing in the town. His Majesty's sloop *Badger* was dismasted and driven ashore in the harbor. All the barracks, huts, and other buildings were blown down, and all the ships were driven to sea.

At St. Christopher several vessels were driven on shore.

Considerable damage was done at Dominica.

Every building in St. Vincent was blown down. The *Experiment*, of 50, and the *Juno*, a French 40-gun frigate, were entirely destroyed.

At Grenada nineteen sail of loaded Dutch ships were stranded and beat to pieces. The dreadful hurricane, which proved so calamitous to many of the islands, produced in Grenada the effect which the legislature had offered £20,000 to have accomplished: The sugar ants disappeared in an instant before the violence of this tornado.[a]

At Martinico,[b] on the 12th, four ships foundered in Fort Royal Bay and every soul perished. Every house in St. Pierre was blown down, and more than 1,000 persons perished. At Fort Royal town, the cathedral, seven churches, the governor's house, the senate house, the prisons, the hospitals, the barracks, and upward of 1,400 houses were blown down. In the hospital of Notre Dame, 1,600 patients, with the nurses and attendants, were almost all of them buried in the ruins. In the shipwrights' sick house 100 perished. Upward of 9,000 persons were computed to have perished in the island, and the damage estimated at 700,000 louis-d'ors.

At St. Eustatia,[c] on the 10th, at 11 p. m., the sky suddenly blackened all around; it rained violently, and thundered and lightened. In the forenoon the gale increased; seven homeward-bound ships were dashed to pieces and every soul on board perished; nineteen others were driven to sea. In the night every house to the northward and southward was blown down, or washed away, with the inhabitants, into the sea. Some few who had hid themselves in large holes in the mountain were saved. In the afternoon of the 11th the wind shifted suddenly to the eastward and swept every house to the east and west. Between 4,000 and 5,000 persons perished, and the damage was estimated at £150,000. The cathedral and four churches, and the barrack and hospital were left standing.

1781.—On the first of August at Jamaica a gale of wind from the south sunk two loaded vessels and drove 24 others on shore, besides wrecking or driving on shore 73 light vessels.—S. C., vol. 2, p. 499.

1784.—A hurricane began at Jamaica at 8.30 p. m. and continued up to, or later than, 11 p. m. of July 30, sinking, dismasting, or driving on shore every vessel in the harbor except four, causing the loss of numerous lives. The barracks were blown down, killing 5 soldiers. The workhouse was destroyed and 10 of the inmates killed or wounded. During the first three days of August the island of St. Domingo experienced a storm.—S. C., vol. 3, p. 3.

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[a] This is an early example of the misuse of the word tornado.

[b] Now Martinique.

[c] Saint Eustatius.

1785.—A hurricane visited Jamaica on the 27th August.—S. C., vol. 3, p. 7.

1786.—The first storm of this year occurred in August doing most damage at St. Eustatius, where all the shipping was driven to sea and most of the small craft destroyed. It also swept the southern coast of Espanola. Another hurricane swept over Guadeloupe on September 10, doing much damage. On Saturday, the 2d of September, an alarming hurricane threw the inhabitants of Barbados into the utmost consternation. At 11 p. m., when the storm was at its height, a meteor in the southeast issued from a dark cloud, and spreading its diverging rays to a vast circumference, continued, with unabated splendor, near forty minutes.

In the morning of the 3d Carlisle Bay was a scene of desolation; not a vessel had ridden out the storm. In the country great damage was done to houses and crops; many persons killed in the ruins of their own houses.

Jamaica came in for her share this year on the 20th October. The trees were stripped of their leaves and appeared as if fire had passed over them. The shores were covered with aquatic birds killed by dashing themselves against mangroves.—S. C., vol. 3, p. 11.

1787.—According to the record there were three gales at Dominica this year, all in August—one on the 3d, one on the 23d, and one on 29th. A number of houses, all the barracks, and all the vessels in the harbor were wrecked.

In September, on the 23d, Balize experienced a severe hurricane, attended by heavy rains, and as the sea rose the land floods could not flow off, hence great damage was done by the overflow. It is stated that more than 500 persons were thrown down and 100 perished. Dead carcasses and logs of mahogany were floating about in every direction. As many as 11 square-rigged vessels, besides smaller ones, were totally lost.—S. C., Vol. 3, p. 13.

1790.—The little island of Tobago is brought into notice this year by destruction wrought there in August by a hurricane which, among other things, wrecked 20 vessels on the coast. As illustrative of the marvelous things sometimes performed by the hurricane we reproduce an account of what occurred on Mr. Hamilton's estate during this gale. "His new mansion, which had been built upon pillars, was lifted by the tempest and removed to some distance; but, being well made, did not go to pieces. Mrs. Hamilton, two ladies, and five children were in the house and suffered little or no harm. Mr. Hamilton, being absent from home, knew not what had happened; but, returning in the night, which was excessively dark, and, groping for his door, fell over the rubbish left on the spot, and so far hurt himself that he was confined for a week."—S. C., vol. 3, p. 38.

1791.—At daybreak, the 21st of June, it began to rain near the

Havana and continued until half-past 2 in the afternoon of the following day with such force as to cause the greatest flood ever remembered in that country. The royal tobacco mills and the village in which they stood were washed away, and 257 of the inhabitants killed. In the spot where the mills stood, the water, or a partial earthquake, opened the ground to the depth of 45 feet, and in one of the openings a river appeared of the purest water. Where the Count Baretto's house stood was a cavity more than 60 feet deep from which a thick smoke rose. Four leagues from thence the torrent was so great that none of the inhabitants within its reach escaped. All the crops of corn and growing fruits were carried away. Three thousand persons and 11,700 head of cattle are said to have perished in the flood.—Southey, C., vol. 3, p. 48.

1806.—Southey's Chronology, vol. 3, p. 365:

[From the Dominica Journal, September 20, 1806.]

ROSEAU, *September 20.*

We again resume our journal, after an interruption occasioned by the confusion and loss sustained in the office during the late hurricane, one of the greatest calamities this colony has sustained within the memory of its oldest inhabitants. To give a detail of all the particulars of that unfortunate event would be a task impossible to fulfill with accuracy, until things commence to be a little more settled, and that a regular communication with the country should be opened, the roads being entirely destroyed. We shall therefore confine ourselves chiefly to the giving a general idea of the whole, as far as the intelligence received from the different parts of the colony may enable us.

On Tuesday the 9th instant, about 7 o'clock in the evening, the sky became totally overcast, and tremendous flashes of lightning, accompanied by heavy puffs of wind, presaged to the more experienced part of the inhabitants an approaching storm; but few expected it would have been so fatal in its consequences. The wind continued increasing until 10 o'clock, when it began to be accompanied by a most dreadful fall of rain, the effect of which, accompanied by a pitch-like darkness, each moment illuminated by a sheet of livid fire, and the roaring of the wind, which every instant became louder, was awful enough to impress a dread upon the heart of the most intrepid. Soon after, to complete our misfortune, the river Roseau, increased by the heavy rains, overflowed its banks, inundated the town in every direction, and then the destruction became general. Every house which obstructed its passage was thrown down, or carried away by the stream, and a great proportion of their unfortunate inhabitants perished. About 10 o'clock every vessel in the harbor was driven from its moorings, except a small Swedish, schooner, which was cast ashore under the fort a little after midnight; and those which were driven out generally met with the same fate, amounting in the whole, to 16 sail, of different descriptions.

No pen can paint the horrors of that dreadful night; the tremendous noise occasioned by the wind and rain, the roaring of the waters, together with the shock of an earthquake, which was sensibly felt about midnight; the shrieks of the poor sufferers crying for assistance; the terror of those who in their houses heard them and dared not open a door or window to give succor, and who expected momentarily to share the same fate, formed a scene which can hardly be conceived and still more difficult to be described. Fortunately for the inhabitants of the town, and, indeed, for the whole colony, the force of the wind and rain abated about 3 o'clock in the morning and near the same time the water began to fall. If it had continued another hour there is not a doubt that the town would have been destroyed.

The spectacle which presented itself on the return of daylight was horrid beyond every power of description. Heaps of mud and sand (in some places5 or 6 feet deep) through all parts of the town; the form of a street hardly to be discerned; two large streams, or rather torrents, running through the midst of the town; ruins of houses blown down and others brought down by the flood, obstructing every passage; the carcasses of several of the unfortunate victims of this event drawn out from the ruins and lying in the streets, while numbers almost distracted were searching for some near relation or friend who had perished in the storm; the lamentations of those who had lost some of their nearest and dearest connections, joined to the despair of those who had lost their little all, formed together a scene fit to draw tears from the eyes of the most unfeeling.

From the most authentic accounts which have been gathered during the confusion occasioned by this fatal occurrence there has been ascertained to have perished in the town of Roseau and its vicinity 8 white persons of different sexes and ages, 57 free persons of color, and 66 slaves, forming a total of 131, besides numbers of others yet missing, and several wounded.

On Morne Bruce, where that part of the garrison stationed at Roseau is quartered, the whole of the barracks were blown down excepting one. Three men and 1 woman killed, and 1 man wounded.

The planters have equally suffered with the inhabitants of the town. Every plantation on the windward coast of the island from the River Tabarie to Morne Paix Bouche are almost entirely destroyed, only 3 mills standing in the whole extent, and these considerably damaged. No other building left on the sugar or coffee estate, and the numerous inhabitants of that quarter have only for shelter 4 houses situated some distance from the sea, to which most of the white inhabitants have retired. On the different estates on that coast, as far as accounts have reached town, there have perished about 30 negroes and upward of 180 dangerously wounded. Round the coast from River Tabarie, by way of La Soye, the estate which bears the name of that river is perhaps the only one which has not received any considerable damage in this general disaster.

All the plantations to leeward of the island have experienced the effects of the hurricane. Every house from the River Mahaut down to Prince Rupert's either flat or greatly damaged, the town of Portsmouth entirely destroyed, the greatest part of the barracks on Morne Cabrit carried away, and, in general, the whole island offers a scene of devastation and ruin.—S. C., vol. 3, p. 365.

1807.—The Bahama Islands were so desolated by "hurricanes that the inhabitants suffered great hardships in procuring the necessaries of life."—S. C., vol. 3, p. 393.

1812.—October 14 a hurricane devastated Trinidad, Cuba, wrecking 500 houses and very much damaging the Pope's Convent and the hospitals, besides driving on shore or sinking many of the vessels in the harbor of Casilda.—S. C., vol. 3, p. 519.

1813.—The island of Dominica suffered considerably from two hurricanes which succeeded each other within a short time. Several houses were blown down. To add to the calamities of the inhabitants upward of 500 runaway negroes made nightly incursions from the mountains, and, by acts of rebellion, threatened the destruction of the colony.—S. C., vol. 3, p. 521.

1815.—The West Indian Islands, especially the Leeward Islands, desolated by a hurricane which swept over them on August 31 and September 1. It is said that 30 sail were driven on shore at St. Bartholomew alone and 14 totally lost.

A hurricane, on September 20, blew down or unroofed about half the houses in Turks Island besides destroying about 400,000 bushels of salt. A number of vessels were wrecked, and one American vessel lost 22 of her crew and passengers.

On the 28th of October Jamaica suffered very great damage from a hurricane. Several vessels with their crews were lost and others damaged.—S. C., vol. 3, pp. 608, 610.

1859. —On September 2 a hurricance of rather mild form passed over St. Kitts—that is, the center passed right over the island. It wrecked a number of boats, besides other damage. It passed over St. Croix after leaving St. Kitts.—DR. W. J. BRANCH.

1899.—The great hurricane of this year was the one which occurred in August, between the 7th and 14th. It was so violent and caused such widespread destruction that it will certainly be ranked as a historical hurricane, for which reason it is mentioned in this place. Entering the West Indian regions in the vicinity of Guadeloupe, it included in its majestic sweep the Leeward and Virgin Islands, Porto Rico, and the Bahamas, not to mention the damage along the coast of the United States. The desolation and ruin wrought by this monster in the West Indies are fresh in the minds of all and need not be repeated here. This hurricane was peculiar in that it maintained a distinct organized existence for more than a month, finally dissipating in the region of the Mediterranean Sea.—W. H. A.

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U. S. DEPARTMENT OF AGRICULTURE.

WEATHER BUREAU.

WEATHER FOLK-LORE

AND

LOCAL WEATHER SIGNS.

Prepared under the direction of WILLIS L. MOORE, Chief U. S. Weather Bureau.

BY

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PROFESSOR OF METEOROLOGY.

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WEATHER FOLKLORE.

INTRODUCTION.

It is safe to assume that our first parents acquired weather wisdom by observing weather sequences and noting the foreshadowed effects of certain atmospheric conditions on objects animate and inanimate. We may assume further that the knowledge thus acquired was communicated to their descendants, and that it was handed down, with additions and amplifications, from generation to generation. We find in the earliest writings and in the Scriptures expressions of weather wisdom, many of which appear in collections of the popular weather sayings of to-day. Thus by assumption and deduction we know that man has ever employed inherited and acquired weather wisdom in the daily affairs of life. When flocks and herds have constituted his earthly possessions he has been prompted to lead his charges to places of safety when signs of impending storms appeared. As a navigator his interpretation of the signs of the air has, in innumerable instances, enabled him to adopt measures calculated to avert disaster to his frail craft. As an husbandman he has closely scanned the sky, the air, and the earth for signs that would indicate the weather of the coming day and season.

The wisdom thus acquired has been perpetuated in the form of trite sayings or proverbs. Many of these sayings are polished gems of weather lore, others have lost their potency by transfer to foreign lands where dissimilar climatic conditions obtain, and a large proportion have been born of fancy and superstition.

The object of this paper is to segregate from the mass of available data the true sayings that are applicable to the United States, and to combine the material thus collected with reports on local weather signs that have been officially and specially prepared by observers of the United States Weather Bureau.

The laws that govern the distribution of the earth's atmosphere and control its phenomena necessarily produce different results on different parts of the earth's surface. The seasonal distribution of the atmosphere, as indicated by the greater, or so-called permanent, areas of high and low barometric pressure, is governed largely by the temperature of the land and water surfaces. In summer the pressure of the atmosphere is greater and its surface temperature is lower over the oceans than over the continents, and in winter the reverse of these conditions obtains. And the differences in atmospheric pressure and temperature control the seasonal directions of the winds. Similarly the smaller areas of high and low barometric pressure that appear on our daily weather maps produce the varying temperatures and winds, and, incidentally, the weather that we experience from day to day.

In the United States the centers of areas of high barometric pressure generally move in a south of east direction immediately preceded by winds that blow from points between west and north, low temperature for the season, and fair weather. Areas of low barometric pressure, or general storms, usually move in a north of east direction, and the winds in their east quadrants blow from easterly or southerly points of the compass, with high temperature for the season, and precipitation in the form of rain or snow.

Chart No. I shows the distribution of atmospheric pressure and temperature, the circulation of the winds, and the general character of the weather that attends the passage of well-defined areas of high and low barometric pressure over the United States.

It will be observed from the foregoing remarks and Chart No. I that wind directions, as influenced by areas of high and low barometric pressure, produce high and low temperatures, fair and foul weather, and the fact will be recognized that all true popular weather sayings of ancient origin have been coined from the utterances, born of experience, of men who have observed, without understanding the causes thereof, the first indications of approaching weather changes.

References and sayings relating to wind, clouds, atmospheric pressure, temperature, and moisture, the habits and actions of animals and birds, and to plant life will in turn be briefly quoted and discussed, and reference will be made to sayings regarding times, days, and seasons, and the sun, moon, and stars. Many of the sayings quoted have been taken from Weather Proverbs, 1883, by Col. H. H. C. Dunwoody, U. S. Army, and Weather Lore, 1893, by Richard Inwards, F. R. A. S. Finally a summary, illustrated by charts, will be given of local weather signs as observed at regular stations of the Weather Bureau.

WIND.

Every wind has its weather.—*Bacon.*

Charts II to V show, for the several seasons, the winds that usually precede the beginning of rain or snow in the United States.

Weather proverbs that have been based upon observations of the wind conform to a notable degree with modern meteorological knowledge. In the temperate zone of the Northern Hemisphere easterly winds are proverbially rain winds and westerly winds are invariably associated with fair or clearing weather. The reason for this is apparent when the circulation of winds about areas of high barometric pressure, and areas of low barometric pressure, or general storms, is observed.

The Temple of the Winds at Athens indicates the knowledge possessed by the Greeks of the weather that is associated with winds from the various points of the compass. It is a little marble octagon tower, the eight sides of which are built to face the eight principal winds, and on each side is sculptured a human figure, symbolizing the character and qualities of the particular wind it faces. The north wind, which is cold, is represented by the figure of a man warmly clad and blowing on a trumpet made out of a seashell. The northeast wind, which brought, and still brings, to the Athenians cold, snow, and sleet or hail, is figured by an old man with a severe countenance, who is rattling slingstones in a shield, expressing emblematically the noise and power of a hailstorm. The east wind, which brings to Athens rain favorable to the growth of vegetation, is expressed by the image of a young man with flowing hair and open countenance, having his looped-up mantle filled with fruit, honeycomb, and corn. The west wind is indicated by the figure of a slightly-clad and beautiful youth with his lap full of flowers. And so on with the winds from all around the compass, each has its qualities fixed in stone by its appropriate sculptured figure, and thus modern science learns from ancient poetry and art the fact that the climate of Greece has not materially changed, at any rate in respect to winds, after the lapse of about twenty centuries.

> When the wind is in the north,
> The skillful fisher goes not forth;
> When the wind is in the east,
> 'Tis good for neither man nor beast;
> When the wind is in the south,
> It blows the flies in the fish's mouth;
> When the wind is in the west,
> There it is the very best.
>
> *Isaak Walton.*

The terms employed in many proverbs to indicate wind directions are indefinite and confusing. The term north or northerly is often indiscriminately applied to winds blowing from the north quadrants, or from a range of 180° of the compass. As a matter of fact, a variation of the wind of a few points in the compass frequently changes absolutely the character of the weather that it indicates. In the case of north or northerly winds, directions from a few points east of north indicate rain or snow and ofttimes the severest storms to which a great part of the United States is subject. On the other hand, winds from points west of north generally indicate fair or clearing weather. East or easterly winds blow from the eastern quadrants, or from the

180° of the compass between north and south by way of east. From 90° of this semicircle, or from points between east and north, the winds often indicate, as before stated, our most violent storms of wind and snow or rain, while following winds from the southeast quadrant the character of the storms is less severe. South or southerly winds are, in many cases, considered as winds that blow from any part of the southern quadrants. These quadrants also cover one-half of the points of the compass, and their winds indicate weather of a very different character. Winds from the southeast quadrant are rain winds, and those from the southwest quadrant are fair-weather winds. Westerly winds, both from the northwest and the southwest quadrants, are, essentially, fair weather winds, the principal distinction between these winds being that the southwest winds are warm and the northwest winds are cold.

A veering wind, fair weather;
A backing wind, foul weather.

If the wind back against the sun,
Trust it not, for back it will run.

Whether the wind backs or veers depends upon the position of the observer with reference to the approaching or passing storm. If a storm center approaching from a westerly direction passes south of the observer, the wind will back from easterly to westerly by way of north; if the storm center passes north of the observer, the wind will veer from easterly to westerly directions by way of south. When the wind is from a southerly direction and veers to westerly, fair weather will follow; when, on the contrary, it backs from southerly to easterly points, foul weather is likely to follow. The sayings regarding veering and backing winds hold good, therefore, only when the winds veer or back from southerly directions.

In Texas and the Southwest when the wind shifts, with strength, during a drought, expect rain.

In the West and Southwest when brisk winds from the south continue for a day or more, expect a "norther."

Over a great part of the United States a steady and strong south-to-east wind will bring rain within thirty-six hours.

Easterly winds are proverbially bringers of rain, and when they blow from the northeast quadrant in winter heavy snow is likely to be followed by severe cold.

When, during a storm, the wind shifts from the east to the west quadrants, clearing weather will soon follow.

When the wind is from points between west and north and the temperature falls to 40° or below, frost will probably occur.

The strength of the wind and the severity of storms depends upon barometric conditions.

Westerly winds (southwest to northwest) are fair-weather winds.

WEST INDIAN HURRICANES.

During the late summer and early fall months hurricanes occasionally develop in the tropical regions of the Atlantic, near the southern edge of the northeast trade winds, and move westward over or near the West Indies into the Gulf of Mexico or to the southern coasts of the United States. Some of these storms recurve northwestward and then northeastward near the Atlantic coast of the United States, and others recurve northward over the Gulf of Mexico. West Indian hurricanes are the most violent and destructive storms that visit the eastern part of the United States. Happily, their visits to our coasts are not frequent; and their visitations to any individual island of the Windward West Indian group, which lies in the most frequented path of hurricanes, are on an average limited to about one in fifteen to twenty years.

As the tropical storms of the Atlantic move from east to west, the winds that indicate their approach necessarily differ from those that are noted in advance of continental storms of the middle latitudes that move from west to east. In the tropical and subtropical regions of the Atlantic Ocean and the Gulf of Mexico the approach of a hurricane from the eastward is indicated by north to northwest winds, which increase in force as the vortex of the storm approaches. The shift of the winds depends upon whether the center of the storm passes south or north of the observer. If it passes to the southward, the wind goes from northerly to easterly and southerly; if it passes to the northward, the wind goes from northerly to southerly by way of west.

West Indian hurricanes are preceded one to two days by barometer rising slowly above the normal and an unusually clear, cool atmosphere. These conditions are followed by a fall in the barometer and, generally, by a greasy-looking halo around the sun or moon, and by high cirrus or cirro-stratus clouds that are projected in advance of the vortex of the storm. Tufted or rolled clouds with lurid streaks of light and unusual atmospheric colors are in turn followed by rapidly falling barometer and a heavy bank of clouds in the horizon in and from which lightning flashes appear. This is the cloud mass that surrounds the center of the hurricane, which advances westward, in the tropical and subtropical regions, with a velocity of 15 to 20 miles an hour. Closely following the appearance of the cloud mass that surrounds the vortex of the storm, the barometer falls with great rapidity and the wind increases to hurricane force from the north quadrants, the direction within the range of these quadrants being governed by the position of the observer with reference to the path of the storm. The vortex of a hurricane is comparatively small, averaging probably 8 to 10 miles in diameter. In the central area of the vortex the sky overhead is often clear, and light confused winds are experienced. As a rule, places in the direct path of the vortex will experience this period of calm for a period of about one-half hour, when the hurricane winds will again set in from a quarter opposite to that from which they were previously blowing. The barometer then rises rapidly, the winds diminish, and the weather gradually clears. The great whirlwind has passed on its westward course. At the point where, from natural causes, that differ in different cases, the hurricane makes its recurve to the northward its speed lessens to 8 or 10 miles an hour, and its strength often increases. After the recurve to the northeastward has been made and the storm enters the middle latitudes of the ocean or of the United States, its area increases and its intensity generally diminishes.

The West Indian hurricane season is confined practically to the months of August, September, and October. Storms of this class sometimes occur, however, as early as June and as late as November.

The following lines regarding the tropical hurricanes of the Atlantic cover, in the opinion of mariners, the season of their probable occurrence:

June, too soon;
July, stand by;
August, look out you must;
September, remember;
October, all over.
—*Captain Nares.*

The tropical storms of the Pacific Ocean that originate near or to the eastward of the Philippine Islands and move thence westward over the China Sea, or northward near the China and Japan coasts, are called typhoons. These storms present the characteristics noted in connection with West Indian hurricanes. Their season is, however, longer, extending from July to November, with August and September as the months of greatest typhoon frequency. The Indian Ocean and the Bay of Bengal also have storms that conform in character to West Indian hurricanes. Cyclones is the very proper name that is applied to these storms. Their season appears to be somewhat longer than that of the typhoons, and the season of the Bay of Bengal cyclones is assumed as extending from May to November, with occasional storms in April and December.

In addition to the gyrating wind storms enumerated, the greater continental areas, and more especially their coast districts, are subject to strong seasonal winds that result from marked atmospheric pressure and temperature gradients that exist between their coastal and interior regions. The most pronounced winds of this type are the monsoons of southern and southeastern Asia and adjacent waters. The monsoons of southern Asia are due, during the warmer months, to the summer area of low barometric pressure that covers the warm interior of eastern Asia, whereby strong wind currents—the summer monsoons—are drawn from the southern coasts and oceans; and during the colder months, when the interior of Asia is occupied by an area of high barometric pressure of great magnitude, the direction of the monsoon winds is reversed and they blow from the interior over the coasts. The change in the winds or, as it is termed, "the bursting of the monsoon," occurs in May and October, and the winds of these months are often very severe.

During the summer months the greater desert areas are the breeding places of violent whirling storms that are generated by the intense heat of those regions; and the deserts, and the regions that border them, are also swept by strong straight winds that are promoted by sharp gradients in temperature that exist between the desert surfaces and the cooler districts that surround them.

Thus it appears that in various parts of the world, winds, by whatever name they may be known, and in the various forms in which they are experienced, owe their origin primarily to differences in temperature in the atmosphere that overlies the land and water surfaces.

As wind directions and velocities are immediately associated with the distribution of atmospheric pressure, as indicated on weather maps by areas of high and low barometer, the value of systematic observations of the winds in foreseeing weather changes will be discussed under the head "Barometer."

CLOUDS.

Clouds are the storm signals of the sky.

Cloud formation is the beginning of the rain or snow producing process. When the process by which the aqueous vapor of the atmosphere is precipitated or condensed is feeble, clouds only are produced; when the process is stronger, or becomes more active, at the cloud levels, rain or snow results.

Charts VI to IX show the direction of movement of cirrus and cirro-stratus clouds in the United States in the several seasons of the year, and the average time, in hours, of their appearance before precipitation begins, or the average time that elapses between the appearance of these clouds and the development of wind and barometric conditions that in a greater or less degree favor precipitation in the form of rain or snow.

In the United States, and more especially in the middle and northern districts, true cirrus and cirro-stratus clouds are almost invariably observed moving from points between southwest and northwest. The appearance of clouds of this type indicates the presence, or at least the partial development, of a barometric depression to the westward. They are formed by the condensation, in high altitudes and at low temperatures, of the moisture in the air that overflows and is projected eastward from areas of low barometric pressure. When the depressions possess sufficient strength, rain or snow follows the appearance of the clouds within eighteen to thirty-six hours. In such cases the cirrus clouds appear to thicken and merge into cirro-stratus, then into alto-stratus, and finally into stratus and nimbus, when precipitation begins. The lower clouds possess but little value as rain indicators for the reason that they usually come with the rain or precede by very short periods the beginning of precipitation.

Mackerel scales and mare's tails
Make lofty ships carry low sails.

Mackerel clouds in sky,
Expect more wet than dry.

A mackerel sky,
Not twenty-four hours dry.

When cirrus merge into cirro-stratus, and when cumulus increase toward evening and become lower, expect wet weather.

After fine, clear weather the first signs in the sky of a coming change are usually light streaks, curls, wisps, or mottled patches of white distant clouds, which increase and are followed by an overcasting of murky vapor that grows into cloudliness. Usually the higher and more distant such clouds seem to be, the more gradual but general the coming change of weather will prove.—*Fitzroy.*

When cirro-cumulus clouds appear in winter, expect warm and wet weather. When threads of cirrus clouds are brushed back from a westerly direction, expect rain and wind.

If cirrus clouds dissolve and appear to vanish, it is an indication of fine weather.

The mackerel clouds always indicate storm if they first appear about 15° north of west. (Kansas.)

The longer the dry weather has lasted, the less is rain likely to follow the cloudiness of cirrus.

If cirrus clouds form in fine weather with a falling barometer, it is almost sure to rain.—*Howard.*

Cirrus clouds announce the east wind. If their streaks point upward, they indicate rain; if downward, wind and dry weather.—*Howard.*

When cloud streamers point upward, the clouds are falling, or descending, and rain is indicated; when cloud streamers point downward, the clouds are ascending, and dry weather is indicated.

Enough blue sky in the northwest to make a Scotchman a jacket is a sign of approaching clear weather.

When on clear days isolated clouds drive over the zenith from the rain-wind side, rain or snow will follow within twenty-four hours—more likely within a few hours.

Clouds flying against the wind indicate rain.

It will not rain much as long as the sky is clear before the wind; but when clouds fall in against the wind, rain will soon follow.

Evening red and morning gray
Will set the traveler on his way;
But evening gray and morning red
Will bring down rain upon his head.

When it is evening, ye say it will be fair weather, for the sky is red; and in the morning it will be foul weather to-day, for the sky is red and lowering.—***Matthew**, xvi, 2, 3.*

When a heavy cloud comes up in the southwest, and seems to settle back again, look out for a storm.

When ye see a cloud rise out of the west, straightway ye say: There cometh a shower; and so it is.—*Luke, xii, 54.*

If clouds at the same height drive up with the wind, and gradually become thinner and descend, expect fine weather.

If the upper current of clouds come from the northwest in the morning, a fine day will ensue.

A sky covered with clouds need not cause apprehension, if the latter are high, and of no great density, and the air is still, the barometer at the same time being high. Rain falling under such circumstances is generally light, or of not long continuance.—*Jenyns.*

It never clouds up in a June night for a rain.

If two strata of clouds appear in hot weather to move in different directions, they indicate thunder.

If clouds float at different heights and rates, but generally in opposite directions, expect heavy rains.

A horizontal streak or band of clouds immediately in front of the mountains on the east side of Salt Lake Valley is an indication of rain within one or two days. When black clouds cover the western horizon, rain will follow soon, and extend to the eastward over the valley.—*Observer at Salt Lake.*

General squalls are preceded, accompanied, or followed by clouds; but the dangerous white squall of the West Indies is indicated only by a rushing sound and by white wave crests to windward.—*Fitzroy.*

A small, fast-growing black cloud in violent motion, seen in the Tropics, is called the "bull's eye," and precedes the most terrible hurricanes.

When you observe greenish-tinted masses of composite cloud collect in the southeast and remain there for several hours, expect a succession of heavy rains and gales.

When the clouds rise in terraces of white, soon will the country of the corn priests be pierced with the arrows of rain. (Zuñi Indians.)

When the cumulus clouds are smaller at sunset than they were at noon, expect fair weather.

When cumulus clouds become heaped up to leeward during a strong wind at sunset, thunder may be expected during the night.

Well-defined cumulus clouds forming a few hours after sunrise, increasing toward the middle of the day, and decreasing toward evening are indicative of settled weather; if instead of subsiding in the evening and leaving the sky clear they keep increasing, they are indicative of wet.—*Jenyns.*

Clouds upon hills, if rising, do not bring rain; if falling, rain follows.

When Lookout Mountain (Tennessee) has its cap on, it will rain in six hours.

BAROMETER.

At the level of the sea the weight of the atmosphere is about 14 pounds to every square inch, or about 1 ton to every square foot of the earth's surface. The barometer is used to gauge the weight or pressure of the atmosphere. This pressure is constantly varying, and the variations are instantly and accurately indicated by standard mercurial barometers. The indications thus furnished by the barometer are the best guide we now have for determining future weather conditions. As low barometer readings generally attend stormy weather, and high barometer readings are usually associated with clearing or fair weather, it follows that, as a rule, falling barometer indicates precipitation and wind, and rising barometer fair weather or the approach of fair weather. Upon the rapidity of the barometric changes depends the character of the weather that follows.. As atmospheric waves and depressions are, by natural laws, caused to assume circular or oval forms, the wind directions with reference to barometric depressions, or areas of low barometer, are spirally inward toward the region of lowest atmospheric pressure, as indicated by readings of the barometer. The areas of low barometric pressure are, in fact, whirlwinds of greater or less magnitude and intensity, depending upon the steepness of the barometric gradient. The crests of the atmospheric waves, on the contrary, show winds flowing spirally outward from the region of highest barometric pressure.

The wind directions thus produced give rise to, and are responsible for, all local weather signs. The south winds bring warmth, the north winds cold, the east winds, in the middle latitudes, indicate the approach from the westward of a low barometer, or storm area, and the west winds show that the storm area has passed to the eastward. The indications of the barometer generally forerun the shifts of the wind. This much is shown by local observations.

In modern meteorological work, as conducted by the United States Weather Bureau, observations, simultaneously taken, are collected by telegraph from great areas, and it is possible by this means to calculate for periods of one to three days in advance the local signs that will be produced by the general conditions that are presented. In other words, modern meteorological appliances, methods, and skill make possible forecasts of the conditions that produce the local signs upon which all weather proverbs are based. Furthermore, it is now practicable not only to forecast general weather changes, but also to calculate with great accuracy the intensity and duration of storms.

The barometer and wind indications for the United States are generally summarized in the following table:

Barometer reduced to sea level.	Wind direction.	Character of weather indicated.
30.10 to 30.20 and steady..............	SW. to NW ..	Fair with slight temperature changes for 1 to 2 days.
30.10 to 30.20 and rising rapidly	SW. to NW .	Fair followed within 2 days by warmer and rain.
30.10 to 30.20 and falling slowly......	SW. to NW .	Warmer with rain in 24 to 36 hours.
30.10 to 30.20 and falling rapidly	SW. to NW .	Warmer with rain in 18 to 24 hours.
30.20 and above and stationary	SW. to NW .	Continued fair with no decided temperature change.
30.20 and above and falling slowly ..	SW. to NW .	Slowly rising temperature and fair for 2 days.
30.10 to 30.20 and falling slowly......	S. to SE.....	Rain within 24 hours.
30. 10 to 30.20 and falling rapidly	S. to SE.....	Wind increasing in force with rain within 12 to 24 hours.
30.10 to 30.20 and falling slowly......	SE. to NE...	Rain in 12 to 18 hours.
30.10 to 30.20 and falling rapidly.....	SE. to NE...	Increasing wind with rain within 12 hours.
30.10 and above and falling slowly...	E. to NE....	In summer, with light winds, rain may not fall for several days. In winter rain within 24 hours.

Barometer reduced to sea level.	Wind direction.	Character of weather indicated.
30.10 and above and falling rapidly..	E. to NE....	In summer rain probable within 12 to 24 hours. In winter rain or snow, with increasing winds, will often set in, when the barometer begins to fall and the wind sets in from the NE.
30 or below and falling slowly.......	SE. to NE...	Rain will continue 1 to 2 days.
30 or below and falling rapidly......	SE. to NE...	Rain with high wind, followed within 24 hours by clearing and cooler.
30 or below and rising slowly........	S. to SW....	Clearing within a few hours, and continued fair for several days.
29.80 or below and falling rapidly ...	S. to E......	Severe storm of wind and rain or snow imminent, followed within 24 hours by clearing and colder.
29.80 or below and falling rapidly ...	E. to N	Severe northeast gales and heavy rain or snow, followed in winter by a cold wave.
29.80 or below and rising rapidly	Going to W.	Clearing and colder.

Northerly and southerly winds may be classed with either fair or storm winds. When they blow from points west of north and south they are fair-weather winds; when from points east of north and south they are foul-weather winds.

During the colder months, when the land temperatures are below the water temperatures of the oceans and the Gulf of Mexico, precipitation will begin when the wind shifts and blows steadily from the water over the land without regard to the height of the barometer. In such cases the moisture in the warm ocean winds is condensed by the cold of the continental area. During the summer months, on the contrary, the on-shore winds are not necessarily rain winds, for the reason that they are cooler than the land surfaces and their capacity for moisture is increased by the warmth that is communicated to them by the land surface. In such cases thunderstorms commonly occur when the ocean winds are intercepted by mountain ranges or peaks. If, however, the easterly winds increase in force, with falling barometer, the approach of an area of low barometric pressure from the westward is indicated and rain will follow within a day or two.

Rapid changes in the barometer indicate early and marked changes in the weather.

A sudden rise in the barometer is very nearly as dangerous as a sudden fall, because it shows that the level is unsteady. In an ordinary gale the wind often blows hardest when the barometer is just beginning to rise, directly after having been very low.

Should the barometer continue low when the sky becomes clear, expect more rain within twenty-four hours.—*C. L. Prince.*

If the barometer fall gradually for several days during the continuance of fine weather, much wet will probably ensue in the end. In like manner, if it keep rising while the wet continues, the weather, after a day or two, is likely to set in fair for some time.—*Jenyns.*

A very low barometer is usually attendant upon stormy weather, with wind and rain at intervals, but the latter not necessarily in any great quantity. If the weather, notwithstanding a very low barometer, is fine and calm, it is not to be depended upon; a change may come on very suddenly.—*Jenyns.*

If the barometer and thermometer both rise together,
It is a very sure sign of coming fine weather.

If the barometer falls two or three tenths of an inch in four hours, expect a gale of wind.—*C. L. Prince.*

If you observe that the surface of the mercury in the barometer vibrates upon the approach of a storm, you may expect the gale to be severe.—*C. L. Prince.*

In summer, when the barometer falls suddenly, expect a thunderstorm; and if it does not rise again when the storm ceases, there will be several days of unsettled weather.—*C. L. Prince.*

A summer thunderstorm which does not much depress the barometer will be very local and of slight consequence.—*C. L. Prince.*

When the barometer falls considerably without any particular change of weather, you may be certain that a violent storm is raging at a distance.—*C. L. Prince.*

In winter heavy rain is indicated by a decrease of pressure and an increase in temperature.—*C. L. Prince.*

The barometer falls lower for high winds than for heavy rain.

When the glass falls low,
Prepare for a blow;
When it rises high,
Let all your kites fly.
—*Nautical.*

First rise after low,
Foretells stronger blow;
Long foretold (falling), long last;
Short notice, soon past.
—*Fitzroy.*

Charts X to XIII show, for various sections of the United States, the point to which the barometer falls, in the several seasons, before precipitation begins. These readings apply more particularly to storms that advance from the west and northwest, and records show, in connection with storms that advance from the directions named, that precipitation seldom begins before the barometer falls to or below the figures given. In the case of storms that advance from the southwest or south, which are indicated by winds blowing from points between east and north, precipitation will, as before stated, often begin when the barometer begins to fall.

From the Mississippi and Missouri valleys to the Atlantic coast, and on the Pacific coast, rain generally begins on a falling barometer, while in the Rocky Mountain and plateau districts, and on the eastern Rocky Mountain slope, precipitation seldom begins until the barometer begins to rise, after a fall. This is true as regards the eastern half of the country, however, only during the colder months, and in the presence of general storms that may occur at other seasons. In the warmer months summer showers and thunderstorms usually come about the time the barometer turns from falling to rising. The fact that during practically the entire year precipitation on the great western plains and in the mountain regions that lie between the plains and the Pacific coast districts does not begin until the center of the low barometer area has passed to the eastward or southward and the wind has shifted to the northern quadrants, with rising barometer, is an important one to the forecaster.

UNSEASONABLE WEATHER DUE TO ABNORMAL BAROMETRIC CONDITIONS.

As local weather conditions are associated with the areas of high and low barometric pressure that appear on our daily weather maps, so are these areas of high and low pressure apparently controlled, both as regards intensity and movement by the great so-called permanent continental and oceanic areas of high and low barometer. The apparent relations referred to are discussed by the writer as follows in the Monthly Weather Review for June, 1902:

> The cause of unseasonable weather is not demonstrable. Neither is it possible in all cases to determine which of the general atmospheric conditions that are associated with unseasonable weather partake of the nature of cause and which of effect.
>
> It has been observed that summer periods of low temperature are associated with barometric pressure below the normal and abundant rainfall, and that summer periods of excessive heat are associated with barometric pressure about or above the normal and a marked deficiency in rainfall. It has also been observed that winter periods of excessive cold are associated with barometric pressure above the normal and little or no precipitation, and that periods of high temperature in winter are associated with barometric pressure below the normal and rain or snow. It has been observed further that the general atmospheric conditions referred to are associated with areas of high and low barometric pressure that traverse the United States. In summer the atmosphere over regions subjected to unusual cold and abnormally heavy rainfall is dominated by areas of low barometric pressure, or general storms that follow unusual tracks for the season, and the atmosphere over regions subjected to unusual heat is undisturbed by the passage of general storms, and is dominated by an extensive and almost stationary area of high barometric pressure. In winter periods of excessive cold are experienced in connection with areas of high barometric pressure of great magnitude that advance from the British Northwest Territory, and also in connection with general storms that follow abnormal southerly paths, and periods of unusually warm weather occur in connection with a succession of general storms that pursue abnormal northerly paths.
>
> A study of the daily meteorological charts of the Northern Hemisphere shows that the general atmospheric conditions over the United States that are associated with unseasonable weather in any part of the country are, in turn, associated with atmospheric conditions that obtain over at least a great part of the Northern Hemisphere. The international charts show that when a period of abnormal weather prevails over a considerable area of the United States, there is a disarrangement of the normal distribution of atmospheric pressure over a great part of the Northern Hemisphere. They show that in the presence of unseasonable weather in any part of the Northern Hemisphere the so-called permanent continental and oceanic areas of high and low barometric pressure present abnormal aspects, and there is an interruption in the normal succession and progression of the areas of high and low barometric pressure of the middle latitudes.
>
> Admitting the possibility of a primary cause of unseasonable weather that first affects the earth's atmosphere as a whole, by disarranging the normal distribution of atmospheric pressure and finally interrupts the usual succession over the continents and oceans of areas of high barometer and general storms, there is presented a fascinating field for speculation and study. Speculation regarding the nature of the cause would naturally be directed toward supposed evidence of solar disturbances as indicated by sun spots, to manifestations of the electro-magnetic influence of the sun's radiant energy, or perhaps to planetary or other equally obscure and possibly

imaginary influences. Study should begin with facts presented at the surface of the earth. In the outline of these facts the association of periods of unseasonable weather with local, continental, and hemispherical barometric pressure has been shown.

A study of international meteorological reports, conducted with a due regard for the facts referred to, would be calculated to lead to a determination of the relation between changes and movements in the smaller and the greater barometric areas with some cause that is external to the earth's atmosphere. It is possible, also, that study carried along these lines would lead to the discovery that periods of unseasonable weather in any part of the Northern Hemisphere are preceded days, and perhaps weeks, by certain changes in the hemispherical system of barometric pressure, and that all the changes and conditions that are observed in our atmosphere and all kinds and types of weather that we experience are subject to definable laws of causation.

THE PHYSICAL EFFECT ON ANIMAL LIFE OF CHANGES IN ATMOSPHERIC PRESSURE.

As the normal pressure, or weight, of the atmosphere is about 1 ton to every square foot of surface at the level of the sea, and a change of 1 inch in the mercurial column of the barometer means a change in pressure of about 70 pounds to every square foot of surface, decided changes in atmospheric pressure must exert a marked influence upon the body and its functions. A change in the barometer of 1 inch in twenty-four hours is not uncommon in many parts of the United States, and this change in the barometer causes a change of about one-half ton in the weight of the atmosphere that is sustained by the average human body. It is not difficult, therefore, to imagine that the physical organism of animals may be sensitive to these changes, and that it has become an inherited instinct to associate the sensations experienced under different atmospheric pressures with the kinds of weather they indicate. The organization of diseased and delicate human bodies, and of many kinds of animals is extremely sensitive to atmospheric changes, and aches, pains, and nervousness in humans, and restless behavior on the part of animals, birds, and insects may, in a measure, be attributed to low, rapidly decreasing atmospheric pressure that precedes and attends storm periods.

Birds fly high when the barometer is high and fly low when the barometer is low. The explanation of this fact is that when the barometer is high the air is heavier and denser and has more sustaining capacity, and birds are therefore able to fly or soar high with less effort than would be required at times when the barometer is low and the air less dense.

Everything is lovely and the goose honks high.

Wild geese fly high in pleasant weather and low in bad weather.

The low flight of rooks indicates rain.

When the cuckoo is heard in low lands, it indicates rain; when on high lands, fair weather.

When swallows in evenings fly high and chirp, fair weather follows; when low, rain follows.

> When swallows fleet soar high and sport in air,
> He told us that the welkin would be clear.
>
> —*Gay.*

Cranes soaring aloft and quietly in the air foreshows fair weather, but if they make much noise, as if consulting which way to go, it foreshadows a storm that's near at hand.—*Thomas Willsford.*

Martins fly low before and during rainy weather.—*Colonel Dunwoody.*

When men-of-war hawks fly high, it is a sign of a clear sky; when they fly low, prepare for a blow.

Bees will not swarm before a near storm.

When bees remain in their hives or fly but a short distance, expect rain.

Smoke falls to the ground preceding rain.

Men work better, eat more, and sleep sounder when the barometer is high.

Do business with men when the wind is from the westerly; for then the barometer is high.

TEMPERATURE.

During the warmer months the temperature generally rises, with falling barometer, before rain, and falls, with rising barometer, after rain begins. During the colder months the temperature usually rises and continues above the normal, before and during rain or snow, and begins to fall, with rising barometer, about the time the rain or snow ends. The rainy periods of summer are cool and the rain or snow periods of winter are warm for the season.

Charts XIV to XXI show for the several seasons the wind directions that attend periods of abnormally high and low temperature in the United States. In the interior of the country periods of high temperature are naturally associated with southerly and southwesterly winds, and periods of low temperature with westerly and northwesterly winds. The charts of wind directions referred to show that on the Atlantic, Pacific, and Gulf coasts, and on the Great Lakes, the water temperature modifies the heat of summer and the cold of winter when on-shore winds prevail.

The changes in temperature before, during, and after storms also have an effect on animal and plant life, and many proverbs are based upon observations of these effects. As, however, changes, in temperature are direct results of wind directions, sayings regarding temperature are almost invariably associated with those relating to the wind.

The warmth of the south wind is enervating.

The cold of the north wind is bracing.

The chill of the east wind is conducive to aches and pains.

The prevailing west winds and moderate temperatures impart the dominating qualities that are possessed by the peoples of the temperate zone.

In the summer, when the sun burns more than usual, expect thunderstorms.

If the temperature increases between 9 p. m. and midnight, when the sky is cloudless, expect rain; and if, during a long and severe period of low temperature, the temperature increases between midnight and morning, expect a thaw.—*C. L. Prince.*

HUMIDITY.

The temperature of the air increases before rain, the capacity of the air for moisture increases with increasing temperature, and the rain winds of the United States are from the oceans and the Gulf. It follows, therefore, that there is an increase in the humidity of the air before rain. It does not follow, however, that every increase in humidity at the earth's surface indicates rain, for in the coast districts an increase in humidity may result from a shift of the wind that causes it to blow temporarily from over the water, and a temporary increase is sometimes due to fog, and neither of these conditions necessarily indicates rain. Ignoring purely local and temporary causes and conditions, however, it may be assumed that, as a rule, general rains are preceded twelve to twenty-four hours by an increase in atmospheric moisture.

The presence in the air of varying amounts of moisture is indicated by the quality that various substances possess to absorb moisture, and by the effect of increasing and decreasing amounts of air moisture on animal and plant life and on many inanimate objects. It is also probable that the moisture of the air shares with atmospheric pressure and temperature in producing good and ill effects on animal and plant life. Warm, moist air attends falling and low barometer, and under these conditions there is feeling of physical and mental lassitude that is in striking contrast to the feeling of exhilaration that accompanies the cool, dry winds that attend rising and high barometer.

Observations to determine the amount and relative amount of atmospheric moisture are usually made with wet and dry bulb thermometers. The wet-bulb thermometer is moistened and the evaporation of the moisture from the bulb cools its surface. When the air is saturated with moisture no evaporation takes place, the air about the instrument will contain no more moisture, and the relative humidity is 100 per cent. The drier the air the more rapid will be the process of evaporation and the greater will be the difference between the readings of the wet and dry bulb thermometers. Hygrometers are constructed which depend for a record upon the effect of moisture on hair that has been specially prepared for this purpose; these devices do not, however, possess a sufficient degree of accuracy to meet the needs of scientific work. Neither do twice-daily readings of the dry and wet bulb thermometers afford sufficient data for a satisfactory study of the relation between atmospheric moisture and rainfall, and until some means can be devised and utilized for securing continuous records of atmospheric moisture for comparison with similar records of atmospheric pressure and temperature this important factor in the production of precipitation and frost can not be properly utilized in the work of weather forecasting.

The following proverbs are based upon the effects of atmospheric moisture that have been observed preceding rain:

Rain comes from a mass of vapor which is cooled.—*Aristotle.*

Mountains cool the uplifted vapor, converting it again into water.—*Aristotle.*

A red sun has water in his eye.

The greater the difference between the readings of the wet and dry bulb thermometers the greater will be the probability of fine weather, and vice versa.—*C. L. Prince.*

When walls are unusually damp rain is expected.

Horses sweating in the stable is a sign of rain.

Doors and windows are hard to shut in damp weather.

Flies sting and are more troublesome than usual when the humidity increases before rain.

Sailors note the tightening of the cordage on ships as a sign of coming rain.

Sensitive plants contract their leaves and blossoms when the humidity increases.

A piece of seaweed hung up will become damp previous to rain.

A lump of hemp acts as a good hygrometer and prognosticates rain when it is damp.

Tobacco becomes moist preceding rain.

When rheumatic people complain of more than ordinary pains it will probably rain.

When the locks turn damp in the scalp house surely it will rain.—*American Indians.*

If corns, wounds, and sores itch or ache more than usual rain is likely to fall shortly.

When matting on the floor is shrinking, dry weather may be expected. When matting expands, expect wet weather.

Ropes shorten with an increase of humidity.

Ropes being difficult to untwist indicate rain.

Quarries of stone and slate indicate rain by a moist exudation from the stones

Salt increases in weight before rain.

A farmer's wife says when her cheese salt is soft it will rain; when getting dry fair weather may be expected.

If metal plates and dishes sweat it is a sign of bad weather.—*Pliny.*

Three foggy or misty mornings indicate rain. (Oregon.)

A rising fog indicates fair weather; if the fog settles down expect rain.

Fog from seaward, fair weather; fog from landward, rain. (New England.)

Hoar frost indicates rain.

Heavy frosts bring heavy rain; no frosts, no rain. (California.)

The larger the halo about the moon the nearer the rain clouds and the sooner the rain may be expected.

When the perfume of flowers is unusually perceptible rain may be expected.

When the mountain moss is soft and limpid expect rain. When mountain moss is dry and brittle expect clear weather.

Sunflower raising its head indicates rain.

Rainbow in morning, shepherds take warning;
Rainbow at night, shepherds' delight.

Rainbow at night, sailors' delight;
Rainbow in morning, sailors' warning.

Rainbow in morning shows that shower is west of us and that we will probably get it. Rainbow in the evening shows that shower is east of us and is passing off.

Snakes expose themselves on the approach of rain.

In dry weather, when creeks and springs that have gone dry become moist, or, as we may say, begin to sweat, it indicates approaching rain. Many springs that have gone dry will give a good flow of water just before rain.—*J. E. Walter, Kansas.*

Drains, ditches, and dunghills are more offensive before rain.

Floors saturated with oil become very damp just before rain.

Guitar strings shorten before rain.

Human hair (red) curls and kinks at the approach of a storm, and restraightens after the storm.

Lamp wicks crackle, candles burn dim, soot falls down, smoke descends, walls and pavements are damp, and disagreeable odors arise from ditches and gutters before rain.

Pipes for smoking tobacco become indicative of the state of the air. When the scent is longer retained than usual and seems denser and more powerful it often forebodes a storm.

Soap covered with moisture indicates bad weather.

Refractions of light of any remarkable kind frequently forebode rain, sometimes storms; at sea the knowledge of this is very useful. Circles around the sun and moon, mock suns, and other phenomena of this kind, together with the unusual elevation of distant coasts, masts of ships, etc., particularly when the refracted images are inverted, are known to be frequent foreboders of stormy weather.

ANIMALS.

The observations of naturalists, shepherds, herdsmen, and others who have been brought much into contact with animals, have proved most clearly that these creatures are cognizant of approaching changes in the state of the air long before we know of their coming by other signs. To many kinds of animals, birds, and insects, the weather is of so much more importance than to us, that it would be wonderful if nature had not provided them with a more keenly prophetic instinct in this respect. The occurrence of a storm would, doubtless, be the means of depriving some of the Carnivora of a meal, and it is known that utter destruction would occur to the nests of some birds if the tenents were absent during a gale of wind or a pelting shower; while to vast numbers of insects the state of the weather for the fraction of a week may determine the whole time during which they may enjoy their little lives. To enable all these creatures to prepare for coming trouble, they seem to have been fitted with what is to us an unknown sense informing them of minute changes in the atmosphere, and it has long been observed that they eat with more avidity, return to their homes, or become unusually restless before the coming of the danger of which they are forwarned.—*Weather Lore.*

Cats have the reputation of being weather wise, an old notion which has given rise to a most extensive folklore. It is almost universally believed that good weather may be expected when the cat washes herself, but bad when she licks her coat against the grain, or washes her face over her ears, or sits with her tail to the fire.

When cattle go out to pasture and lie down early in the day it indicates early rain.

Dogs making holes in the ground, eating grass in the morning, or refusing meat are said to indicate coming rain.—*Colonel Dunwoody.*

All shepherds agree in saying that before a storm comes sheep become frisky, leap, and butt or "box" each other.—*Folklore Journal.*

When horses and cattle stretch out their necks and sniff the air it will rain.

Horses, as well as other domestic animals, foretell the coming of rain by starting more than ordinary and appearing in other respects restless and uneasy.

Hogs crying and running unquietly up and down with hay or litter in their mouths foreshadow a storm to be near at hand.—*Thomas Willsford.*

Kine, when they assemble at one end of a field with their tails to windward, often indicate rain or wind.

When oxen or sheep collect together as if they were seeking shelter a storm may be expected.—*Apache Indians.*

BIRDS.

When birds of long flight hang about home expect a storm.

Migratory birds fly south from cold and north from warm weather. When a severe cyclone is near, they become puzzled and fly in circles, dart in the air, and can be easily decoyed. (North Carolina.)

When birds cease to sing, rain and thunder will probably occur.

Birds and fowls oiling feathers indicate rain.

If fowls roll in the dust and sand, rain is at hand.

Bats flying late in the evening indicate fair weather. Bats who speak flying tell of rain to-morrow.

If cocks crow late and early, clapping their wings occasionally, rain is expected.

If the cock goes crowing to bed,
He'll certainly rise with a watery head.

Chickens, when they pick up small stones and pebbles, and are more noisy than usual, afford, according to Aratus, a sign of rain. Other authors prognosticate the coming of rain from the habit fowls have of rubbing in the dust and clapping their wings.

When chimney swallows circle and call, they speak of rain. (Zuni Indians.)

When cranes make a great noise or scream, expect rain.

One crow flying alone is a sign of foul weather, but if crows fly in pairs expect fine weather.

If the wild geese gang out to sea,
Good weather there will surely be.

If crows make much noise and fly round and round, expect rain.

Wild geese flying past large bodies of water indicate change of weather. Going south, cold; going north, warm.

Guinea fowls squall more than usual before rain.

Clamorous as a parrot against rain.—*Shakespeare.*

Parrots whistling indicate rain.

Gulls will soar aloft, and, circling around, utter shrill cries before a storm.

When grouse drum at night, Indians predict a deep fall of snow.

When the peacock loudly bawls,
Soon we'll have both rain and squalls.

When herons fly up and down as in doubt where to rest, expect rain.

Martins fly low before and during rain.

When the voices of blackbirds are unusually shrill, or when blackbirds sing much in the morning, rain will follow.

Pigeons return home unusually early before rain.

If sea fowls retire to the shore or marshes, a storm is approaching.

Loud and long singing of robins denotes rain.

Robins will perch on the topmost branches of trees and whistle when a storm is approaching.

The stormy petrel is found to be a sure token of stormy weather. When these birds gather in numbers in the wake of a ship, the sailors feel sure of an impending tempest.

FISH.

When fish bite readily and swim near the surface, rain may be expected.

Fishes in general, both in salt and fresh waters, are observed to sport most and bite more eagerly before rain than at any other time.

Black-fish in schools indicate an approaching gale.

Air bubbles over clam beds indicate rain.

When pike lie on the bed of a stream quietly, expect rain or wind.

Porpoises, when they sport about ships and chase one another as if in play, and indeed their being numerous on the surface of the sea at any time, is rather a stormy sign. The same may be said of dolphins and grampus. That the cause of these motions is some electrical change in the air seems probable. Wilsford, in his Secrets of Nature, tells us, "Porpoises or sea-hogs, when observed to sport and chase one another about ships, expect then some stormy weather."

Trout jump and herring schools more rapidly before rain.

The appearance of a great number of fish on the west coast of the Gulf of Mexico indicates bad weather and easterly winds.

INSECTS.

A bee was never caught in a shower.

When bees to distance wing their flight,
Days are warm and skies are bright;
But when their flight ends near at home,
Stormy weather is sure to come.

When ants are situated on low ground, their migration may be taken as an indication of approaching heavy rains.

Expect stormy weather when ants travel in lines, and fair weather when they scatter.

Ants are very busy, gnats bite, crickets are lively, spiders come out of their nests, and flies gather in houses just before rain.

If spiders are indolent, rain generally soon follows. Their activity during rain is proof of its short duration.

When flies congregate in swarms, rain follows soon.

When flies bite greedily, expect rain.

Spiders strengthening their webs indicates rain.

If garden spiders forsake their cobwebs, rain is at hand.

When you see the ground covered with spider webs which are wet with dew, and there is no dew on the ground, it is a sign of rain before night, for the spiders are putting up umbrellas; but others say when the spiders put out their sunshades it will be a hot day.

PLANTS.

The odor of flowers is more apparent just before a shower (when the air is moist) than at any other time.

Cottonwood and quaking asp trees turn up their leaves before rain.

When the leaves of the sugar maple tree are turned upside down, expect rain.

The convolvulus folds up its petals at the approach of rain.

Before rain the leaves of the lime, sycamore, plane, and poplar trees show a great deal more of their under surface when trembling in the wind.

Clover leaves turned up so as to show light under side indicate approaching rain.

Corn fodder dry and crisp indicates fair weather; but damp and limp, rain. It is very sensitive to hygrometric changes.

When the pink-eyed pimpernel closes in the daytime, it is a sign of rain.

Milkweed closing at night indicates rain.

Mushrooms and toadstools are numerous before rain.

The pitcher plant opens its mouth before rain.

Trees grow dark before a storm.

When the leaves of trees curl, with the wind from the south, it indicates rain.

SUN.

The sun, moon, and stars indicate impending weather changes only so far as their appearance is affected by existing atmospheric conditions.

> The sun reveals the secrets of the sky,
> And who dares give the source of light the lie.
>
> *Virgil.*

> The sun sets weeping in the lowly west,
> Witnessing storms to come, woe, and unrest.
>
> *Shakespeare.*

When the sun sets unhappily (with a hazy veiled face), then will the morning be angry with wind, storm, and sand. (Zuñi Indians.)

> Above the rest, the sun who never lies,
> Foretells the change of weather in the skies;
> For if he rise unwilling to his race,
> Clouds on his brow and spots upon his face,
> Or if through mists he shoot his sullen beams,
> Frugal of light in loose and straggling streams,
> Suspect a drizzling day and southern rain,
> Fatal to fruits, and flocks, and promised grain.
>
> *Virgil.*

Since the colors and duration of twilight, especially at evening, depend upon the amount of condensed vapor which the atmosphere contains, these appearances should afford some indications of the weather which may be expected to succeed. The following are some of the rules which are relied upon by seamen: When after sunset the western sky is of a whitish yellow, and this tint extends a great height, it is probable that it will rain during the night or next day. Gaudy or unusual hues, with hard, definitely outlined clouds, foretell rain and probable wind. If the sun before setting appears diffuse and of a brilliant white, it foretells storm. If it sets in a sky slightly purple, the atmosphere near the zenith being of a bright blue, we may rely upon fine weather.—*Weather Proverbs.*

If the sun sets in dark, heavy clouds, expect rain next day.

A red morn, that ever yet betokened
Wreck to the seamen, tempest to the field,
Sorrow to shepherds, woe unto the birds,
Gust and foul flaws to herdmen and herds.
Shakespeare.

When the sun sets bright and clear,
An easterly wind you need not fear.

When the sun draws water, rain follows soon.

Sun drawing water indicates rain.

If the sun draws water in the morning it will rain before night.

The sun setting after a fine day behind a heavy bank of clouds, with a falling barometer, is generally indicative of rain or snow, according to the season, either in the night or next morning.—*Jenyns.*

When it is evening ye say it will be fair weather: for the sky is red. And in the morning, it will be foul weather today: for the sky is red and lowring.—*Matthew xvi, 2, 3.*

An evening grey and a morning red
Will send the shepherd wet to bed.

Evening red and morning gray,
Two sure signs of one fine day.

Red skies in the evening precede fine to-morrows.

When the sun in the morning is breaking through the clouds and scorching, a thunderstorm follows in the afternoon.

A blur or haziness about the sun indicates a storm.

A solar halo indicates bad weather.

Next mark the features of the God of Day;
Most certain signs to mortals they convey,
When fresh he breaks the portals of the east,
And when his wearied coursers sink to rest.
If bright he rise, from speck and tarnish clear,
Throughout the day no rain or tempest fear.
If cloudless his full orb descend at night,
To-morrow's sun will rise and shine as bright.
But if returning to the eastern sky,
A hollow blackness on his center lie;
Or north and south his lengthened beams extend,
These signs a stormy wind or rain portend.
Observe if shorn of circling rays his head,
And o'er his face a veil of redness spread;
Far o'er the plains the God of Winds will sweep,
Lashing the troubled bosom of the deep.
If in a shroud of blackness he appear,
Forewarned, take heed—a drenching rain is near
If black and red their tints together blend,
And to his face a murky purple lend,
Soon will the wolfish wind tempestuous howl,
And the big clouds along the welkin roll.
And foul weather expect, when thou canst trace
A baleful halo circling Phœbus' face
Of murky darkness, and approaching near:
If of two circles, fouler weather fear.

Mark when from eastern wave his rays emerge,
And ere he quench them in the western surge,
If near th' horizon ruddy clouds arise,
Mocking the solar orb in form and size:
If two such satellites the sun attend,
Soon will tempestuous rain from heaven descend:
If one, and north, the northern wind prevails;
If one, and south, expect the southern gales.

J. Lamb's "Aratus."

MOON.

The moon and the weather
May change together;
But change of the moon
Does not change the weather.
If we'd no moon at all,
And that may seem strange,
We still should have weather
That's subject to change.

"Notes and Queries."

The circle of the moon never filled a pond; the circle of the sun wets a shepherd.

If the full moon rises clear, expect fine weather.

A lunar halo indicates rain, and the larger the halo the sooner the rain may be expected.

Last night the moon had a golden ring,
But to-night no moon I see.
If the moon show a silver shield,
Be not afraid to reap your field;
But if she rises halved round,
Soon will tread on deluged ground.

A large ring around the moon and low clouds indicate rain in twenty-four hours; a small ring and high clouds, rain in several days.

The moon with a circle brings water in her beak.

The moon, if in house be, cloud it will, rain soon will come. (Zuñi Indians.)

If the full moon rise pale, expect rain.

When the moon rises red and appears large, with clouds, expect rain in twelve hours.

Therefore the moon, the governor of the floods,
Pale in her anger, washes all the air
That rheumatic diseases do abound.

Shakespeare.

The moon, her face if red be,
Of water speaks she. (Zuñi Indians.)

When the moon is darkest near the horizon, expect rain.

Each sign observe—more sure when two agree;
Nor doubt the event foretold by omens three.
Note well the events of the preceding year,
And with the rising and setting stars compare.
But chiefly look to Cynthia's varying face;
There surest signs of coming weather trace.
Observe when twice four days she veils her light,
Nor cheers with silvery ray the dreary night.
Mark these prognostics through the circling year,
And wisely for the rain, the wind, the storm prepare:

A halo oft fair Cynthia's face surrounds,
With single, double, or with triple bounds;
If with one ring and broken it appear,
Sailors, beware! the driving gale is near.
Unbroken if it vanisheth away—
Serene the air, and smooth the tranquil sea.
The double halo boisterous weather brings,
And furious tempests follow triple rings.
These signs from Cynthia's varying orb arise—
Forewarn the prudent, and direct the wise.

J. Lamb's "Aratus.'

STARS.

When the stars flicker in a dark background, rain or snow follows soon.

When the stars begin to huddle,
The earth will soon become a puddle.

Before the rising of a wind the lesser stars are not visible, even on a clear night.—*Pliny, XVIII, 80.*

When the sky seems very full of stars, expect rain, or, in winter, frost.

Excessive twinkling of stars indicates heavy dews, rain, or snow, or stormy weather in the near future.

When the stars above 45° in altitude, or the North Star, flickers strangely, or appears closer than usual, expect rain.

When the stars appear to be numerous, very large, and dull, and do not twinkle, expect rain.

Now mark where high upon the zodiac line
The stars of lustre-lacking Cancer shine.
Near to the constellation's southern bound
Phatne, a nebulous bright spot, is found.
On either side this cloud, nor distant far,
Glitters to north and south a little star.
Though not conspicuous, yet these two are famed—
The Onoi by ancient sages named.
If when the sky around be bright and clear,
Sudden from sight the Phatne disappear,
And the two Onoi north and south are seen
Ready to meet—no obstacle between—
The welkin soon will blacken with rain,
And torrents rush along the thirsty plain.
If black the Phatne, and the Onoi clear,
Sure sign again that drenching showers are near.
And if the northern star be lost to sight,
While still the southern glitters fair and bright,
Notus will blow. But if the southern fail,
And clear the northern, Boreas will prevail.
And as the skies above, the waves below
Signs of the rising wind and tempest show.

J. Lamb's "Aratus."

When the bright gems that night's black vault adorn
But faintly shine—of half their radiance shorn—
And not by cloud obscured or dimmed to sight
By the fine silvery veil of Cynthia's light,
But of themselves appear to faint away,
They warning give of a tempestuous day.

J. Lamb's "Aratus.

LONG-RANGE WEATHER FORECASTS.

In the early ages when the classes and the masses of the leading nations of the earth were deficient in educational qualifications even to the extent of ordinary clerical accomplishments, the human mind was particularly receptive to assumptions on the part of so-called sages and wise men of a knowledge of coming events. In later days semicivilized and barbarous peoples have given credence to the prophesies of their priests and medicine men, and to-day fakirs and clarlatans in the various professional and scientific fields, astrologers, fortune-tellers, and long-range weather forecasters command, in civilized communities, a lucrative following.

Long-range weather forecasts have ever been impossible of achievement. The period for which weather changes and conditions can be forecast varies from two to three days, depending necessarily, in each instance, on the season of the year and existing atmospheric conditions.

Several methods are employed in the compilation of so-called long-range weather forecasts. The first method, and the only one that possesses merit, being a statement based upon average weather conditions that have prevailed at certain times and seasons in given localities or sections. The main, and fatal, weakness in this system is that average weather conditions are seldom experienced. Average weather conditions are made up largely of extremes, and the probability of experiencing average weather lessens as the length of the period lessens. The average weather for a year differs but slightly from the normal of many years. The seasons possess each year the same general characteristics as regards temperature, precipitation, and winds. The months exhibit, year after year, the same general type of weather. For periods of less than a month, however, averages possess but little value in weather forecasting, and attempts to specify in detail the weather conditions for weeks, months, or seasons in advance are, for all practical purpose, valueless.

Long-range weather forecasts based upon astronomical events, or upon the appearance of the heavenly bodies, can not stand the test of verification, and careful examinations and comparisons have failed to establish any connection between the movements, positions, and changes of the sun, moon, and stars with changes in the weather that are experienced from day to day. Neither can it be shown that the actions of animals, birds, and fish, or the condition of plant life, give evidence of other than present or past weather conditions; and long-range weather forecasts based upon the condition of the weather on certain days have for a basis superstition and ignorance.

It will be interesting, however, to quote and discuss, under the several heads, proverbs, or sayings, that embody long-range forecasts that have been handed down, in many instances, through centuries of time. As all weather sayings relating to the sun apply more particularly to the character of the weather as regards sunshine, on specified calendar and church days, a reference will be made to sayings of this class under the heading, "Days, months, seasons, and years."

SUN SPOTS.

A favorite theory among meteorologists is that sun spots have a definite influence upon meteorological as well as upon magnetic and electrical conditions, and that the more or less well-defined eleven-year period of sun-spot maximum can be directly associated with rainfall and the distribution of temperature and barometric pressure.

Prof. F. H. Bigelow, of the United States Weather Bureau, has recently written as follows regarding the relation between sun spots and terrestrial phenomena:

> The variation in the solar output, as registered in the relative frequency of solar spots, has long been known to have a marked synchronism with the horizontal component of terrestrial magnetism. The sun spots constitute but a sluggish register of the solar activity, and the curve of terrestrial magnetic force presents a series of characteristic miner fluctuations superimposed on the general eleven-year curve. These special variations reappear with marked distinctness in the frequency of the solar prominences; and they are coordinate with the variations of themean annual barometric pressures all over the earth. The pressures in the earth's atmosphere are undergoing changes in short cycles of about three years in duration, which correspond with changes in the external work of the sun, and the cycles are produced by the modifications in the general circulation of the atmosphere. There is, besides, a sort of surging of the atmosphere with more or less stationary configurations, and these involve the seasonal climatic changes of weather by which one year differs from another. Thus the regions about the Indian Ocean and South America vary synchronously, but inversely; the continental and ocean areas do the same. There seems to be a tendency toward a greater cyclic change with a period of about eight years, within which the pressure excesses begin, for example, in India, pass through Asia, Europe, North America, and South America back to India. This synchronism between solar and terrestrial variations holds, in the United States, for the pressures, temperatures, storm-track movements in longitude and latitude, cold-wave tracks, etc.

Commenting upon this summary, the New York Sun of April 26, 1903, remarks:

> Meteorology has a deep interest in elucidating these fundamental relations of solar and terrestrial physics, since upon this depends our hope of making seasonal forecasts upon a scientific basis.

In a recent article Sir Joseph Norman Lockyer remarks regarding this subject, as follows:

> Everybody agrees that all the energy utilized on this planet of ours, with the single exception of that supplied by the tides, comes from the sun. We are all familiar with the changes due to the earth's daily rotation bringing us now on the side of our planet illumined by the sun, then plunging us into darkness; that changes of season must necessarily follow from the earth's yearly journey around the sun is universally recognized.

On the other hand, it is a modern idea that these solar phenomena which prove to us considerable changes of temperature in the sun itself, may, and indeed should, be echoed by the changes on our planet, giving us thereby an eleven-year period to be considered, as well as a year and a day.

This response of the earth to solar changes was first observed in the continuous record of those instruments which register for us the earth's magnetism at any one place. The magnetic effects were strongest when there were more spots, taking them as indicators of solar changes. Lamont first (without knowing it) made this out at the beginning of the latter half of the century (1851) from the Göttingen observations of the daily range of the declination needle. Sabine the next year not only announced the same cycle in the violence of the "magnetic storms" observed at Toronto, but at once attributed them to solar influence, the two cycles running concurrently. It is now universally recognized that terrestrial magnetic effects, including auroræ, minutely echo the solar changes.

The eleven-year period is not one to be neglected. Next comes the inquiry in relation to meteorology. Sir William Herschel, in the first year of the nineteenth century, when there were practically neither sun-spot nor rainfall observations available, did not hesitate to attack the question whether the price of wheat was affected by the many or few spot solar condition. He found the price to be high when the sun was spotless, and vice versa.

By 1872, however, we had both rainfall and sun-spot observations, and the cycle of the latter had been made out. Meldrum, the most distinguished meteorologist living at the time, and others, pronounced that the rainfall was greatest at sun-spot maximum, and, further, that the greatest number of cyclones occurred in the East and West Indies at the same time.

This result with regard to rainfall was not generally accepted, but Chambers showed shortly afterwards an undoubted connection between the cycles of solar spots and barometric pressure in the Indian area. An attempt has been recently made to study the temperature history of the sun since 1877, and the years of mean temperature, and when the heat was in excess and defect.

In the year 1900 Camille Flammarion, the French scientist, observed the great sun spots, including the one discovered by Abbé Mareux, and predicted that the earth was about to enter upon a period of five years, the summers of which would be the hottest in its history. Continuing a discussion of the relation between sun spots and weather, the Chicago Chronicle of July 28, 1901, states as follows:

Camille Flammarion bids fair to make good his prophecy. Yet even now meteorologists and astronomers refuse to believe that he has established any direct connection between terrestrial weather and spots on the sun. Such a connection has for a long time been suspected, but nothing definite in the way of a law has been discovered.

That we shall soon be in a position to forecast the seasons by means of a study of the chemical or physical condition of the sun seems likely. The sun, far from being a great star of unvarying physical characteristics, varies very materially and is very much hotter and brighter at certain periods than it is at others. Its probable temperature at its normal state is about 12,632° F., or 7,000° C., but its radiation of heat year by year is not even, so that in certain years the earth receives much more heat than it does in others, and in consequence important meteorologic changes are set up, the precise nature of which science seems to be just on the edge of unraveling.

For instance, the British astronomer Sir Norman Lockyer has just announced his conclusion that the seasonal rainfall and great heats in India follow certain changes in the sun, and that the famines of India, which bring such unspeakable misery and woe to the teeming millions of this unfortunate country, can be forecast from known solar changes. But as the weather of India is not an isolated phenomenon, but is interlocked with that of Africa and this in turn with that of the Western Hemisphere, a weather cycle in one country is unquestionably duplicated in others.

At present, however, no one has worked out the data for the north temperate zone sufficiently to discover what this cyclical change in our weather is that follows the variation of the physical state of the sun. Sir Norman, however, believes we shall get at the law of change before long and will be able to forecast weather over long periods by a study of the sun's surface. For instance, a huge sun spot was observed in the sun recently which was of such magnitude as to cause much surprise among astronomers, since the sun is now at a period when the sun spots are the least frequent. Conditions are, however, shaping themselves for a period of numerous sun spots in 1904, of which the huge spot observed this spring is the forerunner.

Those who are inclined to jump at conclusions connect the abnormal summer of 1900 with the big spot seen during that summer, while the recent hot wave is blamed on the big spot of June, 1901. And they recall the successful forecast of Abbe Mareux, who, basing his views on the sun-spot activities of the spring of 1900, predicted a hot summer. But the scientific world is not convinced that the data show that the hotter sun is followed by hotter terrestrial weather, though it is convinced that there is a law connecting solar changes with weather changes in the earth, even though it is marked in its operation.

Sir Norman in the case of India has found that the famine years precede the period when the sun is normal, while the seasonable rainfall that relieves the drought follows this normal period invariably. If anything retards the return to the normal period, which has been the case from the year 1897 on, the drought and famine periods are prolonged.

Following up this discovery, which is connected with the eleven-year period in sun-spot variation, W. J. S. Lockyer has made another and exceedingly important discovery, that underlying the ordinary sun-spot period of eleven years there is another cycle of greater length, namely, about thirty-five years, and that this cycle not only alters the time of the occurrence of the period of least frequency, but also causes changes in the total spotted area of the sun from one eleven-year period to another. As it is known that the presence of sun spots does affect the frequency of the aurora borealis and the magnetic phenomena on the earth, great sun spots being followed by magnetic storms that disturb telegraph and telephone systems the world over, Mr. Lockyer has found there is a thirty-five year period in magnetic phenomena, as he puts it:

"There seems little doubt that during the interval of time covered by the present sun-spot discussion the meteorological phenomena, number of auroræ, and magnetic storms show secular variations of a period of about thirty-five years, the epochs of which harmonize with those of the secular variations of sun spots. As we are beginning to approach another maximum of sun spots which should correspond both in intensity and in time of occurrence after the epoch of the present minimum with that of 1870–1878, it will be interesting to observe whether all the solar, meteorological, and magnetical phenomena of that period will be repeated.

"If there is a more or less exact repetition of meteorological phenomena with the return of the thirty-five year period, then the summer of 1901 should be somewhat like the summer of 1867 and the summers of 1902, 1903, 1904 like those of 1868, 1869, and 1870. If this be so, we are not in for a hot summer (in 1901), as absurd as this may seem in view of the record-breaking character of July, but for a series of cool summers. For, according to the Pennsylvania Hospital records, there were only six days during June, July, August, and September, 1867, when the thermometer ran above 90°, while 1868 for the same months only recorded twelve days above 90°;

1869, fourteen, and 1870, thirty-three days, with the highest temperature only 98°. Moreover, June, 1867, had a rainfall of 11.03 inches, while last June, 1901, had only 1.15 inches to its credit."

From this it would appear that however the thirty-five year cycle may apply for great areas of the earth's surface in the matter of climate variation, Philadelphia hardly reveals it in its recent brand of weather. And yet weather ought to follow general changes, for those who believe the variation in the sun's physical stresses affect the weather are agreed generally that it does it by changes in what are known as the areas of high barometer that belt the globe in the Tropics over the oceans in the summer time.

If this theory be correct, our summer weather ought to be determined by the effect of the sun spots on the oceanic high-pressure areas. And the way in which variations in these high-pressure areas affect our weather can be seen by glancing at the United States hydrographic chart, which shows the normal barometric pressure in inches, as well as the normal temperature lines and the resulting circulation of winds. If the Atlantic high-pressure area is shifted toward the Atlantic coast of the United States, it gives us a circulation that is tropical, and if the pressure continues high over the coast, the whole eastward-moving drift of weather over the continent is held up and a hot wave results, which can not be broken up until the Atlantic pressure is reduced.

The question whether a summer in the United States will be abnormally hot is therefore merely a question as to whether the high pressure over the Atlantic will be shifted toward Bermuda and the Atlantic coast. Of course, such a shift means a shift in the high pressures of the Pacific and Indian oceans, for what affects one great system affects the other, and so the weather all the world around is affected.

That a sun spot should be able to affect terrestrial weather can not be considered remarkable when it is remembered that the spots are evidence of tremendous activities in the sun, being nothing more than huge cyclonic disturbances deep down in the photosphere, often 2,000,000 square miles in area, from whose vortices, in which many earths might float, prominences are whirled miles above the sun's surface. Moreover, the photosphere is more brilliant and hot about the spots than anywhere else on the sun's surface. It has been argued that, inasmuch as the sun spots occupy only an infinitesimal space on the surface of the sun, they are too minute to affect the meteorological results with which they are associated. But Sir Norman Lockyer points out that the greater disturbance of certain zones of solar latitude is more influential than the amount of spotted area determined from spots in various latitudes.

Sun spots may be only millionths of the area, but these prominences form one-sixth of the sun's visible hemisphere, and with these in a state of disturbance the effects upon the earth are very important. The sun spots themselves are only a very feeble indication of the fierce activity of the sun. We are observing those prominences more carefully than we have been able to do in the past. We are taking advantage of new methods of observation, and in a few years we shall be in a much better position than we are now to study the connection of solar and terrestrial meteorology.

As the situation shapes up to-day the scientific world is on the lookout for laws of causation that connect solar changes with the great droughts, great floods, and excessive heat waves that mark our weather at different periods. And it looks as if some clever observer would soon wrest the secret from the sun spots and the vagaries of American summer weather even if none of the suggested periods seem to be revealed in the actual recorded weather data.

It appears, in fact, that while a consensus of opinion of those who have contributed to sun-spot literature is, that solar disturbances, as indicated by sun spots, affect the earth's magnetic and electrical conditions, a definite relation between sun spots and meteorological conditions has not been established. It is, however, possible and even probable, that longer periods of observation will permit comparisons that may define concurrent cycles in sun spots and weather. The idea that the sun controls not only the character of the weather experienced in the several seasons, but also the ordinary and extraordinary weather changes to which we are subjected from day to day, is a popular one, and discoveries in this direction will be welcomed by the meteorologist and the layman.

THE MOON AND THE WEATHER.

That the moon has a controlling influence in matters meteorological is a fixed belief in the minds of the masses, and evidence to the contrary, in the form of weather records that fail utterly to show any connection between moon changes and the weather, has been, and is likely to be, insufficient to change this belief.

The following remarks, pertinent to this subject, appear in the Baltimore Sun of December 6, 1900:

> The eminent astronomer, Sir John Herschel, at one time, from very insufficient data, investigated the subject, and, thinking he had discovered a connection between the moon's changes and the weather, constructed tables based upon the time at which the moon's changes occur before and after noon and midnight. It is, however, greatly to Sir John's credit, that he afterwards thoroughly investigated the subject with a much more complete and extensive series of weather records, and proved conclusively that there is no connection whatever between the moon's changes and the weather, unless it were a slight tendency to clearer skies at night at the time of full moon. The most exhaustive investigations made since then have shown conclusively the correctness of Herschel's later conclusions, except that they discredit any tendency of the full moon to produce clear skies.
>
> There are only three possible ways in which the moon could have any physical connection with the weather or influence it in any way whatever. The first is by reason of the heating effect of the lunar rays upon the earth and its atmosphere. The heating effect of the moon's rays has been measured and found to be less than one hundred-thousandth as much as those of the sun. Such a small amount of heat added to the sun's heat would be absolutely insensible. Another possible way in which it has been thought the moon might influence the weather is by producing atmospheric tides, and, as the ocean tides caused by the moon are greater than those caused by the sun, it was at one time thought that this might be the connection. It has, however, required the most careful investigation to show any atmospheric tides caused by the moon's attraction. A minute effect has been found, but it is too small to be of any importance.
>
> The reason why the moon produces greater oceanic tides than the sun is not that its attraction is greater than that of the sun, for as a matter of fact the sun's attraction on the earth is nearly two hundred times as great as that of the moon, whereas the moon's tide-rising power is about two and one-half times as great as the sun's. This is because the sun is four hundred times as far off, and the difference in the attraction for the body upon the nearest and the farthest side of the earth and for the center of the earth is greater in the case of the moon than the sun, so that on the nearest side, the water being mobile and the body of the earth rigid, the water is

pulled away from the earth, and on the farther side the earth is pulled away from the water to a greater extent by the moon than by the sun.

The only other way in which the moon could possibly influence the weather is by magnetic effects. It does have a measurable effect upon the earth's magnetism, but it has never been shown that variations in the earth's magnetism materially influence the weather, although the variations of the atmospheric electricity is greatly influenced by weather conditions.

The so-called wet or dry moons (and, by the way, there is much difference of opinion as to which is the wet and which is the dry moon), or the inclination of the crescent moon to the horizon, are popularly supposed to indicate the weather for the following month. But this inclination of the crescent to the horizon depends mostly upon the inclination of the ecliptic, an hour or two east of the sun to the horizon, and, to a small extent only, to the latitude of the moon north or south of the ecliptic. The inclination of the ecliptic to the horizon depends upon the time of year, and similar wet or dry moons will always occur about the same time of the year.

According to M. Demtchinski, a Russian engineer and scientist, the attraction of the moon is the chief factor in determining the weather. M. Demtchinski read a paper in September, 1900, before the Meteorological Congress in Paris, "On the possibility of making exact forecasts of the weather for any period in advance." It is said that the data communicated to the congress, supplemented by subsequent results, afford ground for the conviction that the weather may be predicted several years beforehand.

M. Demtchinski has such faith in his theory that he has undertaken the publication at St. Petersburg of a semimonthly journal, Climate, which is printed in four languages, English, French, Russian, and German, and which undertakes to predict the weather over almost the whole northern hemisphere. The first number of Climate appeared March 1, and each number is to be issued sufficiently early to reach the most distant points for which predictions are made before the commencement of the fortnight to which they refer. Thus the Russian forecasts for the first fortnight of May will come out in the beginning of April.

We are assured that the theory has already stood the test of experience. Last year, for example, the day of the morning frosts in May was duly predicted for the Moscow region. In like manner, the eight days' dry period in June was forecast, with the practical suggestion to farmers in central Russia to save their hay. The Russian press for the month of March contained an article by M. Demtchinski giving a forecast of the harvest (spring and winter corn) to be expected in Russia, which was fully borne out by the result. The September frosts and the beginning of the Russian winter were predicted with equal accuracy. Finally, to an inquiry addressed by the Volga shipowners to M. Demtchinski when to expect the closing of navigation, the latter wired in reply, a month beforehand, "Navigation will close the 20th October," which was exactly fulfilled.

The theoretical questions which Climate is to encourage are to be concentrated on the question of the influence of the moon on the weather, and M. Poincaré, a French mathematician and meteorologist, has an article on the subject in the first number. In the estimation of unscientific observers the moon has a great deal to do with the weather, and it is possible that European scientists have discovered the principle upon which it exerts the mysterious influence which every weatherwise rustic has observed from the time when the memory of man runneth not to the contrary.

The following are among oft-quoted sayings regarding the moon that refer to its influence upon weather conditions for considerable periods in advance:

If three days old her face be bright and clear,
No rain or stormy gale the sailors fear;
But if she rise with bright and blushing cheek,
The blustering winds the bending mast will shake.
If dull her face and blunt her horns appear,
On the fourth day a breeze or rain is near.
If on the third she move with horns direct,
Not pointing downward or to heaven erect,
The western wind expect; and drenching rain,
If on the fourth her horns direct remain.
If to the earth her uppor horn she bend,
Cold Boreas from the north his blast will send;
If upward she extend it to the sky,
Loud Notus with his blustering gale is nigh.
When the fourth day around her orb is spread
A circling ring of deep and murky red,
Soon from his cave the God of Storms will rise,
Dashing with foamy waves the lowering skies.
And when fair Cynthia her full orb displays,
Or when unveiled to sight are half her rays,
Then mark the various hues that paint her face,
And thus the fickle weather's changes trace.
If smile her pearly face benign and fair,
Calm and serene will breathe the balmy air;
If with deep blush her maiden cheek be red,
Then boisterous wind the cautious sailors dread;
If sullen blackness hang upon her brow,
From clouds as black will rainy torrents flow.
Not through the month their power these signs extend,
But all their influence with the quarter end.

—*J. Lamb's "Aratus."*

If the new moon, first quarter, full moon, last quarter, occur between—

Summer: 12 and 2 a. m., fair; 2 and 4 a. m., cold and showers; 4 and 6 a. m., rain; 6 and 8 a. m., wind and rain; 8 to 10 a. m., changeable; 10 a. m. to 12 m., frequent showers; 12 to 2 p. m., very rainy; 2 and 4 p. m., changeable; 4 and 6 p. m., fair; 6 and 8 p. m., fair, if wind northwest; 8 and 10 p. m., rainy, if wind south or southwest; 10 to 12 p. m., fair.

Winter: 12 and 2 a. m., frost, unless wind southwest; 2 and 4 a. m., snow and stormy; 4 and 6 a. m., rain; 6 and 8 a. m., stormy; 8 and 10 a. m., cold rain if wind west; 10 and 12 m., cold and high wind; 12 and 2 p. m., snow and rain; 2 and 4 p. m., fair and mild; 4 and 6 p. m., fair; 6 and 8 p. m., fair and frosty if wind northeast or north; 8 and 10 p. m., rain or snow if wind south or southwest; 10 to 12 p. m., fair and frosty.

The above is the table credited to Sir John Herschel. It is claimed, also, that he was not responsible for the table. In any case it is within the power of anyone to test its accuracy as applied to the United States.

If the new moon appear with the points of the crescent turned up the month will be dry. If the points are turned down it will be wet. [Note.—Many sailors believe in the direct opposite of the above. The belief is explained as follows: First—If the crescent will hold water the month will be dry; if not, it will be wet. Second—If the Indian hunter could hang his powderhorn on the crescent he did so, and stayed at home, because he knew that the woods would be too dry to still hunt. If he could not hang his powderhorn upon the crescent he put it on his shoulder and went hunting, because he knew that the woods would be wet and that he could stalk game noiselessly.]

When the moon lies on her back,
Then the sou'-west wind will crack;
When she rises up and nods,
Then north-easters dry the sod.
Reviewer in Symons' Meteorological Magazine, September, 1867.

When the moon lies on her back,
She sucks the wet into her lap.
Ellesmere.

It is sure to be a dry moon if it lies on its back, so you can hang your hat on its horns.—*Welsh Border.*

It appears from the foregoing that popular interpretations of weather indications furnished by the crescent moon differ, and are, in fact, of an opposite character among different classes of people. It is the privilege, therefore, of any and all interested to fit the forecasts to the position of the moon, and, in instances where the results are not satisfactory, to assume that a reverse position of the crescent would satisfy the requirements of the theory.

Go plant the bean when the moon is light,
And you will find that this is right;
Plant the potatoes when the moon is dark,
And to this line you always hark;
But if you vary from this rule,
You will find you are a fool;
If you always follow this rule to the end,
You will always have money to spend.

There is a belief in the minds of many persons that certain vegetables and plants should be seeded or planted during certain phases of the moon. The fact that moon phases are not considered where the processes of seeding and planting are conducted on a large scale and with the strictest regard to business and economic methods appears to refute this belief.

That moonbeams or rays produce certain chemical results seems certain. It is known that fish and some kinds of meat are injured or spoiled when exposed to the light of the moon. To this fact the saying that hogs should be slaughtered in the dark of the moon undoubtedly owes its origin. In the larger hog and cattle slaughtering plants the carcasses and meat are not exposed to the moon's rays; the saying applies, therefore, to primitive out-of-door methods of slaughtering and hog killing.

There is a negro saying that "Chickens should be picked in the dark of the moon." It is perhaps unnecessary to remark that while this saying, in common with other misapplied sayings, can not be properly classed as a weather proverb, a conjunction of a dark-of-the-moon period and a dark, cloudy, and rainy night is most favorable to a practical application of the saying.

THE STARS AND THE WEATHER.

There is a kind of weather lore that has been greatly misinterpreted, in many cases, from a failure to recognize its origin. Before the establishment of the calendar and the setting in order of the period months and seasons of the solar year, it was very necessary to determine the approach of each season in order to facilitate farming operations. At the first this could be done only by watching the rising and setting of the constellations. Thus Hesiod says that when the Pleiades rise the harvest begins. Such sayings have been interpreted as indicating the actual benefit of malevolent influence from stars, but seem, in the first instance, to have depended simply on the necessities of the observer. So the piece of weather lore contained in Job, referring to the sweet influences of the Pleiades, depends on nothing more than the indication of the coming season, as shown by the appearance of these stars.—*St. Louis Star, February 24, 1901.*

The Egyptians and Greeks conducted systematic observations in special buildings which might with justice be termed observatories, albeit not supplied, like ours, with means and methods of a high and complicated order. The great pyramid of Cheops has been claimed for such an observatory, and some writers assume that from an opening in its side the learned priests watched the transits of the stars and the rising of the constellations to determine the march of the various seasons suitable for agriculture or for the irrigation of the people's lands.

ANIMALS, BIRDS, ETC.

There is a mistaken belief that some animals possess a faculty that permits them to anticipate the character of the weather for the coming season. The faculty possessed by animals to interpret the signs of coming weather changes is limited to an instinctive appreciation of present atmospheric conditions, which are indicative of certain weather changes for periods of probably one to twelve hours in advance.

It is evident upon consideration that the physical condition of animals, and the thickness of the fur of fur-bearing animals, depends upon the weather of the past and the extent to which it has affected their food supply and general health, rather than upon the weather of the future. And the line of reasoning also applies to plants which are made the subject of future-weather sayings.

Dr. C. C. Abbott showed that the autumnal habits of certain animals that are popularly supposed to be indicative of the character of the coming winter could not be depended upon, although by the majority of people living in the country they were considered as sure indications of what the coming winter would prove to be. Dr. Abbott had kept a careful record, extending over twenty years, regarding the building of winter houses by muskrats, the storing of nuts by squirrels, and other habits of these mammals, and had found that the habits referred to, or their omission, in certain autumns bore no relation to the character of the coming winter.—*Trenton Natural Historical Society meeting, February 13, 1883.*

The following are well-known long-range weather sayings based upon the observed or supposed habits of animals and birds and the appearance and condition of certain plants. It is proper in this connection to again remark that careful investigation has failed to attach a value to sayings of this class:

In early and long winters the beaver cuts his winter supply of wood and prepares his house one month earlier than in mild, late winters.

The beaver begins his preparations for winter when the cold weather sets in; in early winters the cold naturally sets in earlier than in late winters.

Previous to the setting in of winter the mole prepares a sort of basin, forming it in a bed of clay, which will hold about a quart. In this basin a quantity of worms is deposited; and, in order to prevent their escape, they are partly mutilated, but not so much as to kill them. On these worms the moles feed in the winter months. When these basins are few in number the following winter will be mild.—*Gardener's Chronicle.*

The mole, like the beaver, doubtless begins his preparations for the winter when the cold weather sets in; when the cold comes on suddenly and the ground freezes the work of storing worms is interrupted, and the sign is therefore potent only in cases where early spells of cold are followed by comparatively mild winter weather.

Observe which way the hedgehog builds her nest,
To front the north or south, or east or west;
For if 'tis true what common people say,
The wind will blow the quite contrary way.
If by some secret art the hedgehog knows,
So long before, the way in which the winds will blow,
She has an art which many a person lacks
That thinks himself fit to make our almanacks.
—*Poor Robin's Almanack, 1733.*

The hedgehog commonly hath two holes or vents in his den or cave, the one toward the south and the other toward the north; and look which of them he stops, thence will great storms and winds follow.—*Husbandman's Practice.*

The hedgehog undoubtedly stops the windward vent after the wind begins to blow.

If the cat is basking in the sun in February it must go again to the stove in March. (German.)

The average winter shows warm periods in February and cold periods in March.

When bears lay up food in the fall it indicates a cold winter.

If the tracks of bear are seen after the first fall of snow an open mild winter may be expected.

The bear comes out on the 2d of February (Candlemas day), and if he sees his shadow he returns for six weeks.

If on Candlemas day (February 2) it is bright and clear, the ground-hog will stay in his den, thus indicating that more snow and cold are to come; but if it snows or rains he will creep out, as the winter is ended. (German.)

In cold and early winters the chipmunk is very abundant on the south shore of Lake Superior, and are always housed for the winter in October. In short and mild winters they are seen until the 1st of December.

When the flying squirrels sing in midwinter it indicates an early spring.

When the ground squirrel is seen in winter it is a sign that snow is about over.

When squirrels and small animals lay away a larger supply of food than usual it indicates that a long and severe winter will follow.

When squirrrels are scarce in autumn it indicates a cold winter.

The actions of animals, referred to in the sayings quoted, are governed by conditions that exist at the time, and not by a knowledge of future weather conditions.

When birds of passage arrive early in their southern passage severe weather may be looked for soon.

When summer birds take their flight summer goes with them.

Wild geese moving south indicates approaching cold weather; moving north indicates that most of the winter is over.

When wild geese fly to the southeast in the fall, in Kansas, expect a blizzard.

Wild geese flying directly south and very high indicates a very cold winter. When flying low and remaining along the river, in Idaho, they indicate a warm winter. For spring, just the reverse when flying north.

Wild geese flying past large bodies of water indicates change of weather. Going south, cold; going north, warm.

Wild ducks scattered around the lakes near Lake Superior form in large flocks and go south one month earlier in cold or early winters than in mild or pleasant winters.

If cranes appear early in the autumn expect a severe winter.

When the cranes early (in October) fly southward it indicates a cold winter.

The swan builds its nest high before high waters, but low when there will not be unusual rains.

An early appearance of the woodcock indicates the approach of a severe winter.

If crows fly south a severe winter may be expected; if they fly north, the reverse.

When the woodpecker leaves expect a hard winter. When woodpeckers peck low on the trees expect warm weather.

The ivory-billed woodpecker commencing at the bottom end of a tree and going to the top, removing all the outer bark, indicates a hard winter, with deep snow.

Field larks congregating in flocks indicates severe cold.

When wrens are seen in winter expect snow.

When martins appear winter is broken.

No killing frost after martins.

First robins indicate the approach of spring.

If the November goose bone be thick,
So will the winter weather be;
If the November goose bone be thin,
So will the winter weather be.

If the breastbone of a goose is red, or has many red spots, expect a cold and stormy winter; but if only a few spots are visible the winter will be mild.

The whiteness of a goose's breastbone is superstitiously thought to indicate or foreshow the amount of snow during winter.

Birds, like animals, respond to present, rather than to future, weather conditions. Birds of passage begin their southern migration with the first chilling temperatures of autumn, and outtravel the southward advance of the colder weather; and they begin their northern journey when spring temperatures set in at their winter quarters. That their flights are sometimes premature is apparent to close observers.

As regards goose bones, the fact can readily be demonstrated that breastbones of geese, selected with a due regard to time and condition, are contradictory, both as regards their character and the manner of their interpretation.

DAYS, MONTHS, SEASONS, AND YEARS.

Among the first attempts at weather guesses, those concerning the seasons and their probable fitness for agriculture, the breeding of animals, or the navigation of the seas would probably take a prominent place. The weather, during the winter and spring, seems to have been narrowly watched, and the chances of a good harvest, a fat pasture, or a loaded orchard inferred from the experience of previous years, combined with a fair reliance upon fortune. Some of these predictions, though not strengthened by modern observation, are not to be altogether despised or thrown aside. They at least show us what kind of weather our forefathers wished to take place and thought most useful at the times to which they refer. The sayings of French, Scotch, and English agree in many particulars—such, for instance, as those referring to Candlemas day and the early part of February generally. It seems that, according to the notion of our ancestors, this part of the year could not be too cold, and no statistical evidence will ever make our farmers believe that a warm Christmas bodes well for an English harvest, or that a dry year ever did harm to England. Some of these old sayings are also interesting as perhaps indicating the slowly changing climate of England, and it is not unlikely that at some distant date most of the predictions will be found inapplicable. Particular saints' days have been selected as exerting special influence over the weather, and here we are constantly treading on the fringes of the veil of superstition, spread by ignorance over all matters about which but little certain knowledge exists. There are, however, still believers in St. Swithin and St. Valentine as weather prophets; and if their favorites do sometimes fail to bring the expected changes, they have at least no worse guides than those furnished by the Old Moore's and Zadkiel's of modern times.

In considering the weather proverbs regarding certain days, it must be remembered that the new style was first adopted September 2, 1752, eleven days being retrenched from the calendar, i. e., August 22 to September 1, 1752, had no existence in England.—*Weather Lore.*

DAYS.

As the days lengthen,
So the cold strengthens.

As the days begin to shorten,
The heat begins to scorch them.

Fine and unusually warm days during the colder months are called "weather breeders."

If St. Vincent's (January 22) has sunshine,
One hopes much rye and wine.

If St. Paul's (January 25) is bright and clear,
One does hope a good year.

Candlemas Day! Candlemas Day! (February 2)
Half our fire and half our hay.

(That is, we are midway through winter and ought to have half our fuel and hay in stock.)

At Candlemas Day another winter is on its way.

If Candlemas Day be fine and clear,
Corn and fruits will then be dear.

The shepard would rather see the wolf enter his fold on Candlemas Day than the sun.

If Candlemas Day be fair and bright,
Winter will have another flight.

But if Candlemas Day bring clouds and rain,
Winter is gone and won't come again.

On Candlemas Day the bear, badger, or woodchuck comes out to see his shadow at noon; if he does not see it, he remains out; but if he does see it he goes back to his hole for six weeks, and cold weather continues for six weeks longer.

If the ground hog is sunning himself on the 2d of February, he will return for four weeks to his winter quarters.

If a storm on February 2, spring is near; but if that day be bright and clear, the spring will be late.

To St. Valentine the spring is a neighbor.—*French.*

The crocus was dedicated to St. Valentine, and ought to blossom about this time.—*Circle of the Seasons.*

March many weathers rained and blowed,
But March grass never did good.
Fuller.

Dust in March brings grass and foliage.

Snow in March is bad for fruit and grapevine.

March comes in like a lamb and goes out like a lion.

March in January, January in March, I fear.

When March has April weather, April will have March weather.—*French.*

March winds and April showers,
Bring forth May flowers.

St. Patrick's Day (March 17) the warm side of a stone turns up, and the broadback goose begins to lay.

Is't on St. Joseph's Day (March 19) clear,
So follows a fertile year.

Is't on St. Mary's (March 25) bright and clear,
Fertile is said to be the year.

The flower cardamine, or lady's-smock, with its milk-white flowers, is dedicated to the Virgin Mary, and appears about Lady Day (March 25).

If it thunders on All Fools' Day,
It brings good crops of corn and hay.

Hoar-frost on May 1 indicates a good harvest.

If on the 8th of May it rain,
It fortells a wet harvest, men sain.—*T. Fuller.*

Rain on St. Barnabas's Day (June 11) good for grapes.

Before St. John's Day (June 24) we pray for rain, after that we get it anyhow.

Rain on St. John's Day, damage to nuts.

As the dog days (July 3 to August 11) commence, so they end.

Dog days bright and clear
Indicate a good year;
But when accompanied by rain,
We hope for better times in vain.

In this month is St. Swithin's Day (July 15)
On which, if that it rain, they say
Full forty days after it will
Or more or less some rain distill.—*Poor Robin's Almanack, 1697.*

All the tears that St. Swithin can cry,
St. Barthelemy's dusty mantle wipes dry.—*French.*

Alluding to the wet usually prevalent about the middle of July, the saying is: "St. Mary Magdalene is washing her handkerchief to go to her cousin St. James's fair.—*Folk-Lore Journal.*

St. Margeret's flood is proverbial, and it is considered to be well for the harvest in England. (August 1, old style; August 13, new style.)

St. Barthelemy's (August 24) mantle wipes dry
All the tears that St. Swithin can cry.
If the 24th of August be fair and clear,
Then hope for a prosperous autumn that year.

September 15 is said to be a fine day six years out of seven.

St. Matthew's Day (September 21) makes the days and nights equal.

If St. Michael (September 29) brings many acorns, Christmas will cover the fields with snow.

There is often, about October 18, a spell of fine, dry weather, and this has received the name of St. Luke's little summer.

On the 1st of November (All Saints' Day), if the weather hold clear,
An end of wheat sowing do make for the year.

If All Saints' Day will bring out the winter, St. Martin's Day will bring out Indian summer. (United States.)

If on All Saints' Day the beechnut is dry we shall have a hard winter; but if the nut be wet and not light, we may expect a wet winter.

If it is at Martinmas (November 11) fair, dry, and cold, the cold in winter will not last long.

If the leaves of the trees and grape vines do not fall before Martin's Day, a cold winter may be expected.

Expect St. Martin's summer, halcyon days.—*Shakespeare.*

The fourteen halcyon days then began (December 11)—days in which in the Mediterrean a calm weather was expected, so that the halcyon or hawk could (it was supposed) make its nest on the surface of the sea.—*Virgil.*

A green Christmas makes a fat churchyard.

A green Christmas brings a heavy harvest.

If Christmas finds a bridge, he'll break it; if he finds none, he'll make one.

Wednesday clearing, clear till Sunday.

If on Friday it rain,
'Twill on Sunday again;
If Friday be clear,
Have for Sunday no fear.

When it storms on the first Sunday in the month, it will storm every Sunday during that month.

The character of the weather on holidays and church or saints' days, when the masses of the people have forsaken their usual occupations in favor of out-of-door recreation, or the donning of the best wearing apparel, has naturally been a subject of unusual interest and special note. And it has followed from this fact that these days have been, to a greater extent than the ordinary working days, a basis for weather speculation. It will be noted that all sayings relating to these days are of value only so far as it may be assumed that normal weather conditions on those days are favorable and abnormal conditions are unfavorable for seasonable weather in the near future. They may be considered as indicating which way the balance of temperature and precipitation tips at that particular season of the year, and the forecasting feature is found in the statement of weather conditions that will be required to adjust the balance.

MONTHS.

The month that comes in good will go out bad.

A favorable January brings us a good year.

January warm, the Lord have mercy!

If grass grows in January, it grows the worse for it all the year.

Always expect a thaw in January.

If there is no snow before January, there will be the more in March and April.

A warm January, a cold May.

There is always one fine week in February.

If February gives much snow,
A fine summer it doth foreshow.

February rain is only good to fill ditches.

Thunder in February or March, poor sugar (maple) year.

Winds in March and rains in April promise great blessings in May.

As it rains in March, so it rains in June.

A dry and cold March never begs its bread.

March flowers make no summer bowers.

March comes in like a lamb and goes out like a lion.

March comes in like a lion, goes out like a lamb.

March in January, January in March, I fear.

March damp and warm will do the farmer much harm.

When March has April weather, April will have March weather.

March winds and April showers bring forth May flowers.

A cold April the barn will fill.

Moist April, clear June.

Till April's dead, change not a thread (of clothing).

Dry May brings nothing.

May damp and cool fills the barns and wine vats.

A hot May makes a fat churchyard.

To be hoped for, like rain in May.

A dry May is followed by a wet June.

Wet May, dry July.

Calm weather in June sets corn in tune.

June damp and warm does not make the farmer poor.

A cold and wet June spoils the rest of the year.

It never clouds up in a June night for rain.

July, God send thee calm and fayre,
That happy harvest we may see.

As July, so the next January.

Ne'er trust a July sky.

Whatever July and August do boil, September can not fry.

As August, so the next February.

When it rains in August it rains honey and wine.

Dry August and warm
Doth harvest no harm.

As September, so the coming March.

A wet September, drought for next summer. (California.)

Heavy September rains bring drought. (United States.)

Much rain in October, much wind in December.

Warm October, cold February.

If October bring heavy frosts and winds, then will January and February be mild.

As the weather in October, so will it be in the next March.

As November, so the following March.

December cold with snow, good for rye.

SEASONS.

A late spring, a great blessing.

Better late spring and bear, than early blossom and blast.

A late spring never deceives.

If the spring is cold and wet, then the autumn will be cold and dry.

A dry spring, rainy summer.

Early thunder, early spring.

Generally a moist and cool summer portends a hard winter.—*Bacon.*

A pleasant autumn and a mild winter will cause the leaves to fall next September.

A hot and dry summer and autumn, especially if the heat and drought extend far into September, portend an open beginning of winter, and cold to succeed toward the latter part of the winter and beginning of spring.—*Bacon.*

Who doffs his coat on a winter's day
Will gladly put it on in May.

There can never be too much rain before midsummer.

If we do not get our Indian summer in October or November, we shall get it in the winter. (United States.)

A late spring is good for corn, but bad for cattle.

A moist autumn, with a mild winter, is followed by a cold and dry spring, retarding vegetation.

After a rainy winter follows a fruitful spring.

A green winter makes a fat churchyard.

An abundant wheat crop does not follow a mild winter.—*Farmer, quoted in "Notes and Queries."*

A severe autumn denotes a windy summer,
A windy winter a rainy spring,
A rainy spring a severe summer,
A severe summer a windy autumn;
So that the air in balance is
Seldom debtor unto itself.
Bacon.

If the spring is wet and cold, the autumn will be hot and dry.

A warm and open winter portends a hot and dry summer.—*Bacon.*

Midsummer rain spoils wine, stock, and grain.

A warm winter and cold summer never brought a good harvest.—*French.*

Winter will not come till the swamps are full. (United States.)

Winter's back breaks about the middle of February.

Winter under water, dearth; under snow, bread.

YEARS.

A bad year comes in swimming.—*French.*

After a wet year a cold one.

Wet and dry years come in triads.

Rainy year, fruit dear.

Frost year, good year. Snow year, good year.

In the year that plums flourish all else fails. (Devonshire.)

Year of radishes, year of health.

A cow year, a sad year; a bull year, a glad year.—*Dutch.*

A year of grass, good for nothing else. (Switzerland.)

Leap year was ne'er a good sheep year. (Scotland.)

A dry summer through the central part of the United States signifies a deficiency in the corn crop, which means that our ham and bacon will cost us more during the following winter. A wet spring in the wheat belt means a higher price for flour. Unseasonable weather in the South signifies that a few months later we shall be obliged to pay more for cotton goods. A frost in Florida means a higher price for oranges.

AN INNOVATION IN BAROMETRIC OBSERVATION.

In the Monthly Weather Review for January, 1903, the Chief of the United States Weather Bureau introduces a new feature. Among the charts hitherto appearing in that publication has been one showing the mean barometric pressure over the whole country for a month, the readings having been reduced to sea level. It is now proposed to supplement this with two more, giving the computed pressures at elevations of 3,500 and 10,000 feet. Prof. Frank H. Bigelow, upon whose recommendation this innovation is made, and who has, by an elaborate research, made possible the preparation of such charts, hopes that they may in time be of assistance in "seasonal," or long-range, forecasting. Additional data will be required, he says. It will be necessary to know something about temperatures and humidity at the same altitudes. Until these are all available study of the problem can not bear much fruit. Still, a beginning is to be made; and the first step is to note how far the actual pressure for a month at various levels differs from the average of corresponding periods for many years.

Up to the present time no systematic and public predictions of the character here contemplated have been made under governmental auspices anywhere in the world except in India. Those are based on local principles, and are not applicable elsewhere. One factor, for instance, is the weight of the snowfall in the Himalayas during the previous winter. The outcome, too, has not been especially encouraging. Whatever be the success of Professor Bigelow's plan, it is already obvious that its basis is far more rational and his method less empirical than any other which has yet been proposed. He does not, it is safe to assume, expect to be able to indicate the exact details for any particular date and spot, as countless "cranks" attempt to do. The utmost which it will ever be feasible to accomplish in the long-range work, it may be confidently asserted, is to outline the general situation over comparatively wide areas for two or three weeks, or perhaps a month or more, in advance. Yet, if nothing more is accomplished than this—a correct hint of a tendency toward even a trifling excess of heat or cold and a disposition toward an abundance or scarcity of rain—the benefit to the country will be enormous.

It is not incredible that a second advantage may be secured from a more careful examination of conditions existing at two or three standard planes in the upper air. When actual temperatures at various elevations above the earth are ascertained by means of kites, it is found that the rate of decrease with height is not uniform. Sometimes it is more rapid than the established average, and sometimes it is slower. A knowledge of the existence of these abnormal temperatures might help the forecaster in the short-range work now officially sanctioned. At present the Government meteorologists are bothered by several eccentricities in the behavior of those barometric depressions which constitute the chief feature of all daily maps. One is a departure from the ordinary routes which low areas follow in crossing the country; a second is a remarkable variation in their speed; and the third is uncertainty about the amount of rain which will attend them. The last is the most serious in its effects, but they are all highly embarrassing. If, by minimizing such uncertainties, a study of the upper air will improve the daily forecasts, it should be pushed as far as is practicable. At times, the Government service, while all that the present state of meteorological science will permit, perhaps, is far from realizing the ideal of its founders or the demands of the public. If anything better is possible, the country wants it.—*New York Daily Tribune, April 30, 1903.*

LOCAL WEATHER SIGNS.

The following summaries of local weather signs are based on special reports of observers to the Chief of the United States Weather Bureau:

ABILENE, TEX.

During late spring, summer, and early autumn precipitation is usually preceded twelve to twenty-four hours by south to southeast winds and falling barometer, and the barometer generally falls to 29.80 or below before precipitation begins. During the colder months precipitation often begins when the barometer has fallen to 30 and is on the turn from falling to rising, and at the time the wind shifts to colder northwest.

Precipitation is preceded by relative humidity that increases to 75 or 80 per cent.

Cirrus and cirro-stratus clouds move from the west, but the relation of these clouds to rain has not been noted by the observer, who associates stratus and cumulo-nimbus clouds with rain.

The highest winds of winter come from the northwest with rising barometer, and of summer from the southeast with falling barometer.

During periods of abnormally high temperature south to southeast winds prevail, except in summer, when they come from the southwest. During periods of abnormally low temperature the winds are from westerly in spring and winter, and from northwesterly in summer and autumn.

Frost is most likely to damage crops in April and November.

The conditions most favorable for frost are: Rising, or high and stationary, barometer, temperature falling to 40° or below, increasing relative humidity, clear weather or cirrus clouds, and light west to north winds.

ALBANY, N. Y.

Precipitation is usually preceded in all seasons by south and southeast winds, which set in twenty-four to forty-eight hours before precipitation begins, and barometric pressure which usually falls to or below 29.90 to 29.95 in spring and summer, and to 30 inches or below in autumn and winter.

Except in the presence of fog, which indicates clearing weather, the relative humidity generally increases during twenty-four hours preceding precipitation.

Usually, but not necessarily, cirrus clouds moving from the west precede precipitation about twenty-four hours in all seasons. Alto-stratus clouds from the west or southwest usually precede rain from twelve to forty-eight hours. In spring and summer detached cumulus clouds, moving rapidly from the southwest under a veil of alto-stratus, sometimes appear about twelve hours before rain.

In spring, summer, and winter, high north to west winds usually occur with a rising barometer, and in autumn with a falling barometer and wind from the southeast. In all seasons wind is from the south during periods of abnormally high temperature. In spring and winter the cold winds are from the west and north, in summer from west, and in autumn from west to northwest.

Frosts in May and June are most likely to damage fruit, and frosts in September are most likely to damage other crops.

The conditions which precede frost are barometer above 30.12, temperature about 40°, humidity high. In winter there are two kinds of frost, one a shotted-formed frost, the other of a spongy character; the former is observed in advance of "dry" low barometer areas, the latter in advance of storms from the southwest.

ALPENA, MICH.

In spring and summer southeast winds and falling barometer precede precipitation for periods that vary from a few hours to several days, and the barometer usually falls to 29.90 or below before precipitation begins. During the colder months there is frequently light precipitation in the rear of areas of low barometer. In such cases, however, precipitation has occurred in front of the low areas.

Atmospheric moisture is unreliable as an indicator of precipitation, and while in a majority of cases the relative humidity has increased during twenty-four hours preceding precipitation there are many instances of precipitation that have been preceded by a decrease in relative humidity.

The only upper clouds that are at all reliable as indicators of precipitation are the cirro-stratus "veil." These clouds may occur in any season, but are seldom observed. In spring and autumn clouds become stratus several hours before precipitation begins. In summer small, heavy-looking cumulus clouds usually precede rain; in winter stratus and strato-cumulus prevail, and there are but few clear days.

High winds may come from any quarter in any season, but they are more frequent from the northwest with rising barometer. In all seasons abnormally warm winds are usually from the southwest, and cold winds from the west and northwest.

Frost is likely to damage fruit or crops from May 15 to October 1. The conditions favorable for frost are: Clear weather, light winds, decreasing humidity, rising and high barometer, and falling temperature.

AMARILLO, TEX.

South to southeast winds usually set in twenty-four to forty-eight hours before precipitation, with falling barometer, which reaches 29.85 to 29.90 or below in spring and summer and 30.05 or below in autumn and winter. Precipitation begins, however, after the barometer begins to rise, and in the colder months after the wind has shifted to northerly, the most marked exception to this rule being noted in June, when rain commonly begins with falling barometer.

In all seasons there is a rapid decrease in relative humidity until thirty-six to forty-eight hours before precipitation begins in spring and winter, and twenty-four to thirty-six hours before precipitation begins in summer and autumn, and after the minimum per cent has been reached the humidity rapidly increases until rain begins. A sudden and decided increase in humidity indicates precipitation, unless it follows a heavy rain.

In spring cirro-stratus followed by alto-stratus clouds indicate rain. In summer rain follows cirro-stratus, passing through alto-stratus and alto-cumulus to cumulus; in autumn very limited cirro-stratus, soon followed by alto-stratus, and frequently alto-stratus alone precede rain. In winter cirro-stratus are not strongly indicative of precipitation, but usually indicate changes in temperature and wind direction; and precipitation is usually preceded by alto-stratus or stratus clouds. In spring and autumn cirrus or cirro-stratus from west to southwest and in summer and winter from west to northwest are sometimes observed two or three days in advance of precipitation.

Frost is preceded by moderate pressure, low temperature, high relative humidity, light winds, and very few, if any, clouds.

Vegetation of all kinds withstands low temperature remarkably well, but frost from September 1 to October 15 would damage forage crops and range grass when there is sufficient moisture to keep them green.

ATLANTA, GA.

In spring and summer the winds which precede rain come most frequently from east, southeast, and south, and the average length of the period which elapses between the time the wind sets in from these directions and rain begins varies from thirty-four hours in spring to seventeen hours in summer. In autumn northeast to southeast winds usually precede rain for an average period of thirty-three hours. In winter rain is generally preceded by an average period of twenty-two hours by wind from the northeast, east, southeast, or southwest, and snow usually follows after the wind shifts to northwest. In all seasons the barometer generally falls to or below 30 before rain begins and the temperature has been high for the season.

Rain may, as a rule, be expected when the relative humidity exceeds the normal for the season, and the greater the excess the shorter will be the time before the beginning of precipitation.

In spring, autumn, and winter cirrus clouds early in the day, followed by cirro-stratus from the west, usually precede precipitation by ten to fifteen hours. In summer cirrus or cirro-stratus clouds have not been observed, except in thunder-storm formations.

In all seasons the highest winds come from west to northwest, with rising barometer.

In periods of abnormally high temperature the winds are usually from the southwest in spring, from west to northwest in summer, and from southeast to southwest in autumn and winter. During periods of abnormally low temperature, the wind is from the northwest in spring, autumn, and winter, and from east to northeast in summer. Northwest winds are usually dry winds in all seasons.

The general conditions which precede frost are high or rising barometer, temperature 55° and below, low humidity, light to fresh winds, usually from west to north, and clear or clearing weather.

Frost is most likely to damage fruit or other crops during March and April, and cotton during September and October.

ATLANTIC CITY, N. J.

As a rule precipitation is preceded six to twelve hours by easterly winds and falling barometer, except in summer when the wind that precedes showers is usually from south to southwest. In all seasons the barometer generally falls to 30 or below before precipitation begins, and in summer showers occur with the barometer on the turn from falling to rising.

Owing to proximity to the sea and frequent fogs increasing atmospheric moisture is not an indication of rain, except in summer, when an increase in relative humidity is sometimes noticed eight to twelve hours before general rains, and immediately before local rains.

In spring, autumn, and winter the wind increases steadily in velocity until the beginning of precipitation; in summer, however, the wind is usually light before and during local rains, while local rains and thunderstorms are attended by violent squalls.

Cirrus and cirro-stratus clouds moving from the west are often observed twelve to twenty-four hours before precipitation in spring, autumn, and winter, and cirro-stratus clouds one to twelve hours in advance of summer rains.

The highest winds generally come from the northeast with falling barometer. During periods of abnormal heat the wind is westerly in summer and autumn, and southwest in spring. In all seasons the cold winds are from west to northwest.

Garden truck is likely to be damaged by frost in April, May, and September.

Heavy frost is usually preceded by rising barometer, falling temperature, light variable winds, and few if any clouds.

AUGUSTA, GA.

In spring, summer, and autumn precipitation is usually preceded twelve to twenty-four hours by south to east winds and falling barometer, and in all seasons the barometer generally falls to 30 or below before rain begins. In summer showers occur under varying barometric conditions.

In all seasons, except summer, there is a decrease in relative humidity about twelve hours before precipitation begins; in summer the relative humidity increases about four hours before rain begins.

During spring strato-cumulus, and in autumn and winter alto-stratus, clouds usually indicate precipitation. Cirrus clouds, moving from the west, are often observed twenty-four hours before rain in spring, and ten to twelve hours before rain in autumn and winter. In summer cirrus clouds from west to southwest often appear two to four hours before rain. In spring, stratus clouds moving rapidly from north to northeast; in summer, strato-cumulus moving rapidly from east to southeast, and in winter, alto-stratus moving slowly from west, presage precipitation.

During periods of abnormally high temperature the wind is from the south in spring, from the northeast in summer, and from the southeast in autumn and winter. During periods of abnormally low temperature the wind is from north in spring, from west in summer, from northeast in autumn, and from northwest in winter.

Heavy frost after rain in the last decade of October will seriously injure the cotton crop; a heavy frost in the middle and latter part of April will damage the peach crop.

The general conditions favorable for frost in spring are rising barometer, temperature 40°, relative humidity 60 per cent, north wind, and cirrus clouds. In autumn and winter rising, followed by falling and low barometer, temperature 50°, relative humidity 50 per cent, west to northwest winds, and cirrus or cirro-stratus clouds.

BAKER CITY, OREG.

In spring, autumn, and winter precipitation is preceded twenty-four to forty-eight hours by southeast winds and falling barometer; rain that falls in summer storms generally comes with rising barometer. In all seasons, except winter, the barometer falls to 29.85 or 29.95, or below, before precipitation begins; in winter the usual height of the barometer observed at the beginning of rain is about 30.10 inches.

The relative humidity decreases until within twenty-four hours of the beginning of rain. The moisture of the air is unreliable as an indicator of rain, except that the relative humidity is generally low preceding the beginning of precipitation.

In all seasons cirrus, or cirro-stratus clouds moving from the southwest are observed six to seven days before rain. In spring, autumn, and winter rain is generally preceded in the order named by cirrus, cirro-stratus, and stratus clouds, and in summer by cumulo clouds and thunderheads.

During periods of abnormally high temperature the wind is from the southeast in spring, summer, and autumn, and from the southwest in winter. In all seasons during periods of abnormally low temperature the wind is from the south.

Fruit and other crops are most likely to be damaged by frost in April, May, June, September, and October.

The general conditions favorable to frost in summer and autumn are barometer oscillating, temperature changes sudden, wind variable, relative humidity high, cirrus clouds, and clear weather.

BALTIMORE, MD.

In spring the wind sets in from the southeast, and in summer, autumn, and winter from southeast to southwest, with falling barometer before precipitation, and the barometer usually falls to about 30 before rain begins. A wind from northeast to southeast is generally followed by increasing cloudiness, and in the colder months a shift of wind to these directions is closely followed by precipitation.

In about 50 per cent of the instances noted the relative humidity increases for about two days preceding rain.

Cirrus-cloud formations, moving from points between southwest and northwest, are observed twenty-four to forty-eight hours before rain.

The highest winds of spring are from the northwest, of summer from north to northwest, and of autumn and winter from west.

In all seasons during the periods of abnormally high temperature the wind is usually from southeast to southwest, while north to northwest winds generally prevail during periods of abnormally low temperature.

Injury by frost is most likely to occur from the latter part of March to the middle of April. In average seasons crops are safe after that, although damage has been done in the early part of May. In autumn nearly all staple crops of this locality have been gathered before heavy frost occurs. Corn is seldom hurt.

The general conditions favorable to frost are barometer above the normal and rising, falling temperature, decreasing humidity, fair to clear skies, and light north to northwest winds.

BINGHAMTON, N. Y.

East to south winds and falling barometer precede rain twelve to twenty-four hours in spring, autumn, and winter. In summer east to south winds precede rain about twenty-four hours, and the barometer falls until just before the beginning of rain. In all seasons the barometer falls to about 29.90 or 29.95 before rain begins.

Data regarding relative humidity are very incomplete, but in all seasons an increase in relative humidity occurs at least twelve hours in advance of rain.

In about 70 per cent of the instances noted, rain is preceded in all seasons by stratus or strato-cumulus clouds. Cirrus or cirro-stratus clouds, moving from the west, are observed twenty-four to thirty-six hours before precipitation.

The high winds of spring, summer, and autumn are from the west, with rising barometer, and in winter from the south, with falling barometer.

During periods of abnomally high temperature the prevailing winds are from the southwest in spring and summer, from southwest to west in autumn, and from south in winter.

Frost is most likely to damage fruit and other crops in May and September.

The general conditions which precede frost in spring are rising barometer, high temperature followed by rapidly falling temperature early in the afternoon, low humidity, light westerly winds, and clear or rapidly clearing weather in spring and autumn. In autumn the relative humidity increases preceding frost, with the result that dense fogs frequently occur before radiating surfaces reach the freezing point, and radiation is stopped and the frost does not form. Occasionally dense fog occurs after the frost has formed. Frost forecasts for autumn are therefore very difficult to verify.

BISMARCK, N. DAK.

In spring precipitation is preceded by east winds and falling barometer, in summer by southwest winds and barometer "on the turn" from falling to rising, and in autumn and winter with northwest winds and rising barometer. In spring the barometer falls to about 29.80, in summer to about 29.90 before precipitation begins; in autumn the barometer usually stands at about 30, and in winter at about 30 to 30.10, when precipitation begins.

No relation has been observed between the moisture of the air and precipitation.

No observations have been made which connect cirrus or cirro-stratus clouds with approaching precipitation. Neither have any observations been made regarding any special characteristics of cloud formation that presage rain.

The high winds of spring, autumn, and winter are usually from the northwest, with rising barometer, and of summer from southerly, with falling barometer.

During periods of abnormally high temperature the wind is from southeast to south in spring, from south in summer, and from southwest in autumn and winter. During periods of abnormally low temperature the wind is from east to northeast in spring, from east in summer, and from northwest in autumn and winter.

Frost is most likely to damage fruit or other crops in June, August, and September. The general conditions which precede heavy frosts are high barometer, temperature between 30° and 40°, clear weather, and light winds.

BLOCK ISLAND, R. I.

In the spring precipitation is preceded about nine hours by northeast winds and falling barometer, in summer by southwest winds and falling barometer for periods which vary from one to three days, in autumn by northeast winds and falling barometer for ten to twenty-four hours, and in winter by northeast winds and falling barometer for an average period of about ten hours. In all seasons the barometer falls to about 29.90 before precipitation begins, except during the colder months, when precipitation will begin with northeast winds immediately after the barometer begins to fall.

There appears to be a slight increase in relative humidity from one to three days in advance of rain in all seasons; but an increase does not always indicate rain. In many instances the humidity decreases just preceding rain.

In spring, autumn, and winter cirro-stratus clouds moving from the west generally indicate precipitation, and are observed eighteen to twenty-four hours before precipitation begins.

The highest winds of spring are from southeast to southwest, with falling, and from north to northwest with rising barometer; of summer from the southwest with falling barometer; of the autumn from northeast with falling barometer; and of the winter from east to northeast with falling, and from northwest with rising barometer.

During periods of abnormally high temperature the wind is from the southeast to southwest in spring, from the west in summer, from west to south in autumn, and from southeast to south in winter. During periods of abnormally low temperature the wind is from north to northeast in spring, northeast in summer, and north to west in autumn and winter.

On account of the ocean's influence and high average wind velocity frost is infrequent. Freezing temperature after April 15 is, however, liable to do some damage.

BOISE, IDAHO.

In all seasons rain almost invariably begins during the barometric stationary period, or "on the turn" from falling to rising. A steady and regular fall of the barometer may be expected preceding rain, but sharp rises and falls, frequently amounting to 0.10 inch, sometimes occur about the time clearing weather is expected. There are frequently twelve hours of such unsteady barometer after a sufficient rise to warrant fair weather has occurred. The "critical point" of the barometer, as regards precipitation, is not well established. It seems to vary greatly in all seasons and sometimes occurs with the pressure considerably above normal. As a rule, southeast winds set in ten to twelve hours before rain begins in spring, autumn, and winter. In summer the rainfalls are entirely local, and are not necessarily indicated by either wind or barometer conditions.

The moisture of the air can not be depended upon to indicate the approach of rain, and the relative humidity immediately preceding rain, and many times after rain has begun to fall, is surprisingly low.

The clouds preceding rain are usually high cirro-stratus and alto-stratus through which the sun is visible to within a short time preceding the beginning of rain. Lower clouds, coming up quickly, attend the beginning of rain. In spring, autumn, and winter, especially in winter, when cirrus or cirro-stratus clouds are observed in easterly quadrants, unsettled weather usually follows. The halos that result from cirrus clouds are so frequently followed by rain in less than twelve hours that the direction of the clouds during halos has been closely noted. Cirrus and cirro-stratus clouds observed in the west are not forerunners of rain. The best cloud indication of approaching rain is the cirro-stratus observed in the east, whether in spring, autumn, or winter; but in summer the appearance of strato-cumulus, principally in the southwest, is regarded as a good sign of an approaching thunderstorm.

Fruit growers fear the late frosts that occur from about the 10th of May to June 5. It appears that the frosts that occur in spring prior to May 10 are likely to be followed by cloudiness, and the damage which would otherwise result is mitigated thereby. The late frosts are likely to be followed by cloudiness, and the temperature change to much warmer generally does more damage than the frost itself. Fruit is seldom damaged by frost during the fall. Preceding frost the barometer rises with west to northwest winds for twelve hours or more. Under these conditions the temperature falls, the humidity remains high, and heavy lower cumulus clouds appear. Frequently a state of semicloudiness exists after the wind has decreased to a point favorable for frost to form and frost fails to form, except in streaks. Many apparently ideal conditions for frost are turned aside by increasing cloudiness about sunrise.

BOSTON, MASS.

In spring, autumn, and winter precipitation is usually preceded twelve to twenty-four hours by southeast to southwest winds and falling barometer; and in spring, summer, and autumn the barometer generally falls to about 29.90 inches before precipitation begins. In the case of storms that advance from the southern Atlantic coast precipitation closely follows a shift of wind to the northeast and the turn in the barometer from rising to falling. In the spring and winter rapidly rising temperature precedes rain.

There is generally an increase in the humidity of the air preceding well-defined storms or general rains; but, owing to the proximity to the ocean, an increase in humidity is frequently produced by sea breezes and fog when fair weather is assured.

In spring and summer cirrus clouds have not been observed to any marked extent; in autumn and winter cirrus clouds, moving from the west, often precede rain twelve to twenty-four hours. In summer, cirrus and cirrus haze often precede high wind; in autumn, fine types of cirrus and cirro-stratus presage high wind and rain, and these characteristics also obtain for winter.

In spring and autumn high winds usually occur from east to south, with falling barometer. The highest winds of summer generally occur with thunderstorms; in winter high winds occur from east to south, with falling, and from west to northwest with rising, barometer.

During periods of abnormally high temperature southwest winds prevail in spring, summer, and autumn, and south to southwest winds in winter. During periods of abnormally low temperature the direction of the wind is northwest to west in spring and autumn, northeast to north in summer, and northwest in winter.

Frost is most likely to damage fruit or other crops during the last week of May and the first two weeks of June.

The general conditions which precede heavy frost in spring are high and stationary barometer, temperature below the normal, light wind, and clear weather. In autumn the same conditions obtain as in spring, with low humidity.

BUFFALO, N. Y.

In spring and summer precipitation is preceded twelve to eighteen hours by south to southeast winds and falling barometer, and in autumn and winter from eight to fifteen hours by south to southwest winds and falling barometer. The rains of summer usually begin with barometer about 29.80 inches and near the "turn" from falling to rising. In autumn rain also generally begins with barometer near the "turn" from falling to rising, and at a height of about 29.95. In spring precipitation usually begins when the barometer has reached

29.90, and in winter when it has fallen to about 30. In the case of storms that advance from the south or southwest precipitation often begins closely following the shift of wind to the northeast and the turn in the barometer from rising to falling.

As the winds which precede rain are land winds, the relative humidity generally decreases ten to fifteen hours before rain begins.

Cirro-stratus clouds are usually observed twelve hours in advance of rain in spring and summer. In summer cirrus clouds are often seen that are not followed by rain. In autumn and winter cirro-stratus clouds are noted eight to ten hours in advance of rain, but sometimes only a few hours in advance of rain or snow. In all seasons cirrus or cirro-stratus clouds moving from the west or southwest are sometimes observed five to fifteen hours before precipitation begins, the period being longer in spring and summer.

In all seasons maximum wind velocities are usually reached with rising barometer and west to southwest winds.

Precipitation is usually preceded by rising temperature, and begins "on the turn" from rising to falling.

During periods of abnormally high temperature the winds are from the southeast in spring, from south to southeast in summer, from south to southwest in autumn, and from south in winter. During periods of abnormally low temperature the winds are from northwest to northeast in spring and summer, and from north to northeast in autumn and winter.

Frost is most likely to damage fruit or other crops from May 10 to June 1, and from September 10 to October 1.

The general conditions which precede heavy frost are clearing weather, high pressure, temperature which will fall to a point between 40° and 35°, diminishing westerly winds, and clear weather in the morning.

CAIRO, ILL.

The observer has often noticed that when the barometric pressure is near the normal, but falling at the time of the evening observation, rain usually follows within twenty-four hours; on the contrary, with a rising barometer at the evening observation, although cloud conditions portend rain, the weather usually turns out fair. In spring and winter southeast winds usually set in twenty-four to thirty-six hours before precipitation, and precipitation begins with the barometer about stationary or "on the turn" from falling to rising. In summer rain is preceded for an indefinite period by southwest winds, and begins with the barometer rising or "on the turn" from falling to rising. In autumn south to southeast winds precede rain, and rain usually begins with falling or stationary barometer, and often when the barometer is rising or "on the turn" from falling to rising. In spring and summer the barometer usually falls to 29.95 or 29.90 before rain begins; in autumn and winter 30.10 or below before precipitation begins.

In all seasons precipitation is usually preceded by relative humidity about or above normal, or rapidly increasing. However, these conditions are frequently followed by a continuance of fair weather. Precipitation seldom follows within twelve hours an observation at which the moisture of the air is considerably below the normal, except in the winter months, when such conditions are sometimes followed by light snow.

A record of all clouds observed during the day and into the night shows that cirrus and cirro-stratus clouds are as often followed by fair weather as by precipitation. In autumn and winter alto-stratus clouds are usually followed by rain within twenty-four hours; in spring and summer low banks of stratus clouds in the west in the early morning are usually followed by thunderstorms in the afternoon.

During periods of abnormally high temperature the wind is from the southeast and southwest in spring, from southwest to northwest in summer, and from southeast to southwest in autumn and winter. During periods of abnormally low temperature the wind is north to northwest in spring and winter and from northeast to northwest in summer and autumn.

Frost is most likely to damage fruit or other crops any time after April 10 or before November 15.

The conditions which usually precede heavy frost are, barometer normal or above, temperature 36° or below, humidity about normal, gentle winds and cloudless sky.

CAPE MAY, N. J.

In spring and winter precipitation is usually preceded by easterly winds ten to twelve hours, and occasionally by northeast winds which shift to that quarter almost simultaneously with the beginning of rain. In summer winds are usually from south, and in autumn from southwest to southeast, preceding rain. In all seasons the barometer falls to 30 inches or below before rain begins, except when winds shift to the northeast.

The moisture of the air usually increases one to two days preceding rain, and the relative humidity is generally about 90 per cent when precipitation begins.

Cirrus or cirro-stratus clouds moving from the west are often observed one to two days before precipitation in spring, summer, and winter. In autumn alto-stratus clouds usually precede rain.

The high winds of this locality are from the east with falling and from the west with rising barometer.

During periods of abnormally high temperature the winds are from west to northwest in spring, from south to southwest in summer and autumn, and from east to south in winter. During periods of abnormally low temperature the prevailing winds are from west in spring, from northeast in summer, and from northwest in autumn and winter.

Frost is most likely to damage fruit or other crops in April and September. The conditions favorable for frost are high barometer, temperature 40° or below, low humidity, light north to west winds.

CARSON CITY, NEV.

In spring, autumn, and winter the wind usually sets in from west to southwest one to three days before rain begins. In summer precipitation occurs with thunderstorms, and the wind which precedes rain may come from any direction, but generally from west to southwest. In all seasons precipitation is usually preceded by falling barometer, and begins with the barometer "on the turn" from falling to rising. The barometer usually falls to 29.85 or 29.90 inches before rain begins.

Very little relation has been observed between the moisture of the air and rain. It is not believed that the relative humidity increases or decreases to any great extent preceding precipitation.

Cirrus or cirro-status clouds presage rain in all seasons, and are usually observed moving from the west twelve to twenty-four hours before rain begins. Heavy banks of stratus or strato-cumulus clouds over the mountains west of the station, moving rapidly from the west and southwest, presage precipitation at any time during the year.

High winds usually occur from the southwest with falling barometer.

During periods of abnormally high temperature the wind is from the south and southwest in spring, autumn, and winter, and from west in summer. During periods of abnormally low temperature the wind is from west to northwest in spring, autumn, and winter, and from the west in summer. In spring two or three successive days of high temperature are generally followed by thunderstorms and rain, mostly on the surrounding mountains. Moderate barometric depressions are usually followed by decided falls in temperature in all seasons.

Frost is most likely to do damage during the last half of May. Moderately low pressure, increasing temperature and humidity, overcast sky, and precipitation usually precede heavy frost during spring, autumn, and winter.

CHARLESTON, S. C.

In spring rain is preceded twelve to twenty-four hours by falling barometer and southwest winds, and the barometer usually falls to about 30 before rain begins; in summer rain is usually preceded twenty-four to thirty-six hours by southwest winds. The heaviest rains of early summer usually occur with abnormally high barometer and when the barometer is "on the turn" from rising to falling. The period of heavy summer rains sets in about June 10 of each year. In autumn rain is preceded twelve to thirty-six hours by west to southwest winds, and usually with falling barometer, although occasionally with small rise in barometer.

In spring there is a decided increase in relative humidity when winds are from the southwest eight to twenty-four hours before rain. When the wind is from the southeast, east, and northeast there is very slow and slight increase in humidity six to twenty-four hours preceding rain, owing to the fact that the winds from these directions are from the ocean. In summer there is a decided increase in relative humidity eight to twenty-four hours preceding rain when the wind is from the southwest. High humidity, increasing slowly eight to sixteen hours preceding rain, is observed when winds are from the south, southeast, east, and northeast. In autumn there is a rapid increase in humidity six to sixteen hours before rain when winds are from southwest during September; high humidity increasing slowly six to sixteen hours before rain when winds are from south, east, or northeast during October and November; in winter the humidity increases slowly six to sixteen hours before rain with winds from southeast, east, or northeast, and increases rapidly six to sixteen hours before rain with winds from southwest.

In spring cirrus clouds appear immediately after the passage of a crest of high pressure, and assume the cirro-stratus form; alto-stratus next appear, followed by strato-cumulus, when rain begins. Cirro-stratus and alto-stratus are both indicators of rain. In summer the upper clouds play an unimportant part in the prediction of rain. The lower clouds, cumulus and strato-cumulus, more often precede rain than any other clouds. Late in August, however, after a period of frequent thunderstorms, cirro-stratus and alto-stratus appear in advance of approaching tropical storms and can usually be relied upon as forerunners of rain. In autumn cirrus and cirro-stratus clouds are more numerous than in summer, and late in October and November cirrus and cirro-stratus are usually forerunners of rain. In winter cirrus and cirro-stratus clouds, particularly cirro-stratus, are forerunners of rain. The interval between the appearance of cirro-stratus before that of alto-stratus is short, and rain closely follows the formation of alto-stratus clouds. The elevation of the cirrus and cirro-stratus is much lower in winter than in summer, frequently reaching the cumulus and strato-cumulus levels, and their velocity is about twice as great as that of the lower clouds.

Frost is most likely to damage fruit or crops from March 1 to April 25, and from October 25 to December 15. In spring frost is usually preceded by increasing barometer, day temperature—ranging between

50° and 60°—low dew-point, normal humidity, and light winds between southwest and north points. Frost occurs in this section with air temperature as high as 49°, and, in the vicinity of the station, frost has been known to form in ravines and low lands with air temperature about 52°. With other conditions favorable to frost, it rarely occurs with northeast winds. In autumn frost does not form in September and seldom in October. In November when the barometer is rising and winds are from southwest to northwest and decreasing, with cloudless sky, and low dew-point, and an evening temperature of 50°, heavy frost may be expected during the night. Heavy frost can form with observed air temperature as high as 40°. In winter heavy frost occurs with daily night temperature about 45°, relative humidity 70 to 80 per cent, winds light and from southwest to north, clear sky, and high and increasing pressure.

CHARLOTTE, N. C.

In summer and autumn southeast winds and falling barometer precede rain six to twenty-four hours, and rain generally begins with barometer falling or "on the turn" from falling to rising. In all seasons the barometer usually falls to 30 or below before rain begins, except when storms come from the southwest.

The relative humidity increases in advance of thunderstorms in summer, and to a lesser degree in advance of general rains; the period is not definite and may be days or only hours. The amount of moisture in the air is no indication of coming rain as a rule, excepting immediately before a rain. The few observations taken, usually twice a day, are not sufficient to treat questions very favorably.

No definite rule can be made with regard to the relation between cirrus and cirro-stratus clouds and precipitation. Occasionally several veils of cirrus clouds come and go within twenty-four hours of the beginning, especially in autumn. In probably more than one-half of the instances clouds of this type do not precede rain.

In summer the highest wind velocities usually occur with a falling barometer; in autumn and winter the maximum velocities occur more frequently with a rising barometer than in summer. In many cases there are decided rises or falls in the barometer without corresponding wind velocities.

During periods of abnormally high temperature the wind is from the southwest in summer and from south to southwest in autumn. During periods of abnormally low temperature the wind is from the northwest in summer and from northeast to northwest in autumn. (Data regarding the barometer and the wind as indicators of rain has not been furnished from this station for the spring and winter seasons.)

Frost is most likely to damage fruit or other crops after April 1 and before November 1.

Frost is usually preceded by slowly rising barometer, temperature falling or stationary, humidity depending on temperature and clearness of the sky, light winds from northeast to northwest quadrants, and clearly defined cumulus clouds, diminishing at sunset.

CHATTANOOGA, TENN.

In spring south winds and falling barometer precede precipitation twelve to twenty-four hours; in summer northeast winds set in twenty-four hours before rain, and are attended by falling barometer. During a thunderstorm, however, the relation between "rain winds" and the movement of the barometer is variable and uncertain. In autumn the wind and barometer conditions preceding rain are similar to those in spring; in winter northeast winds set in with falling barometer twelve to twenty-four hours before precipitation begins. In all seasons the barometer falls to about 30 on an average before precipitation begins.

The percentage of relative humidity is usually low twenty-four hours in advance of rain; occasionally, however, a gradual increase is noticed for forty-eight hours. In summer there is a gradual increase in atmospheric moisture twenty-four to forty-eight hours preceding general rains; in autumn and winter the relative humidity increases before rain for periods which vary from twenty-four to seventy-two hours.

In general the interval in cirrus and cirro-stratus clouds is only a few hours when rain is approaching, and the change from cirro-stratus to alto-stratus takes place rapidly. All gradations, from cirrus to strato-cumulus in the southwest, are visible. Rain usually follows a quantity of cirro-stratus and alto-stratus clouds within thirty-six hours if their direction is from southwest. In all seasons the prevailing direction of cirro-stratus clouds is from the west. As a rule, when the sky is partly clouded with cirro-stratus clouds from the southwest rain can be expected in thirty-six hours during the spring season; in summer, as a rule, four-tenths, or more, of alto-stratus clouds from westerly directions indicate rain in thirty-six hours; in autumn, when the sky is partly overcast with alto-stratus clouds, moving from the south, southwest, or west, rain may be expected in twenty-four hours; in winter four-tenths, or more, of cirro-stratus or alto-stratus clouds from the southwest or west indicate rain in thirty-six hours; in summer also types of cumulus clouds seen over the northwest, or west, or southwest horizons in the morning indicate thunderstorms in the afternoon.

During periods of abnormally high temperature the prevailing winds are southerly in spring, autumn, and winter, and southwest in summer. During periods of abnormally low temperature the prevailing winds are from the northwest in spring, autumn, and winter, and from the north in summer.

Frost is most likely to damage fruit or other crops from March 1 to May 15, and from September 15 to October 30.

The general conditions which precede frost are rising pressure, falling temperature, decrease in humidity, brisk winds, and clearing weather. Frosts usually occur in the midst of an area of high barometer.

CHEYENNE, WYO.

In spring, autumn, and winter rain or snow usually begins with rising barometer, yet some of the heaviest snowstorms of the winter and spring occur when the barometer is nearly stationary after falling. In all seasons, except winter, the barometer falls to 29.90 or below before precipitation begins, except in winter, when precipitation often begins with the barometer ranging from 30 to 30.15.

A close observation leads to the belief that the humidity observations are of no value at any season in forecasting precipitation at this station. Cirrus or cirro-stratus clouds are sometimes observed moving from the northwest, but the observer states that he has never observed any connection between these clouds and precipitation, and that he can not say that any kind of clouds can be regarded as forerunners of rain.

There are no crops or fruits of any kind grown in this locality which would be damaged by frost, except a very few small garden patches in the city.

CHICAGO, ILL.

In general the barometer begins to fall, with southerly winds, ten to twelve hours before precipitation begins. In the case of summer thunderstorms the barometer usually falls quite rapidly two to six hours before the storm; during the storm the barometer rises suddenly and then again falls gradually. Clearing weather is nearly always preceded by rising barometer; the rise, however, may not be more than an hour or so in advance of the clearing weather.

In spring an increase in humidity frequently becomes apparent twenty-four hours before rain (especially in March) when winds set in from the east quadrants, this increase becoming pronounced twelve hours in advance. Snow is most frequent with relative humidity 60 to 80 per cent. In summer and autumn decreasing humidity usually precedes rain twelve to twenty-four hours, the decrease being marked ten to twelve hours before rain begins. In winter precipitation is preceded more frequently by increasing humidity, although it often follows decreasing humidity. It can hardly be said that the moisture in the air, with its surface local variations, as expressed in relative humidity, is a reliable index of rain in this locality. Low, high, increasing, and decreasing humidity are all followed by rain, and nearly as frequently by no rain. Months and years differ decidedly in this respect; the only marked fact is that a considerable decrease in humidity usually precedes summer storms.

Cirrus and cirro-stratus clouds are not so frequent in March, but in April and May they usually precede rain, appearing one to two days in advance. However, cirrus and cirro-stratus clouds occur with equal frequency that are not followed by rain. In summer cirrus and more frequently cirro-stratus clouds appear in advance of rain, but these clouds appear with even greater frequency before fair weather. In autumn strato-cumulus clouds are forerunners of rain, but upper clouds appear very frequently without being followed by rain. In winter cirrus and cirro-stratus clouds appear frequently before rain, and much more frequently they are not followed by rain or snow. The cirrus and cirro-stratus clouds observed usually move from the west in spring, summer, and winter, and from southwest to west in autumn. A lowering or transforming of cirro-stratus to strato-cumulus most frequently precedes rain from six to twelve hours; also cumulo-stratus from southwest finally taking the surface wind direction. This applies to both spring and summer. In autumn a lowering of alto-stratus and strato-cumulus into stratus occurs two to twelve hours in advance of precipitation, and in winter a lowering of cirro-stratus to stratus and then to nimbus occurs two to twelve hours in advance of rain or snow.

In spring high winds are usually southerly with falling and southwest with rising barometer; in summer south to southwest with falling barometer; in autumn south with falling barometer; and in winter south with falling, and west, northwest, and northeast with rising barometer.

Frost is most likely to damage fruits or other crops from April 10 to May 10, and from September 25 to October 10.

Heavy frost in spring and autumn is usually preceded by moderately high pressure, temperature 40° or below, high humidity if light and low humidity if heavy frost, light winds, and cloudless sky.

CINCINNATI, OHIO.

In spring, summer, and autumn precipitation is most frequently preceded twelve to forty-eight hours by southeast winds and falling barometer, and the barometer usually falls to 30 or below before precipitation begins; in winter precipitation is preceded by south to southwest winds, and the barometer falls to about 29.90 before rain begins. In nearly every case during rain periods the rain continues when the barometer is "on the turn" and rising. When the rain is light the barometer remains nearly stationary previous to beginning and during its continuance.

Humidity observations appear to be of little value in forecasting. In general there is an increase in humidity before rain, but for what period in advance can not be determined. The fact is recognized that when we say, "It feels like rain or snow," the feeling is produced by increasing atmospheric dampness.

No observations have been made with regard to the extent that cirrus, cirro-stratus, or other clouds are forerunners of rain.

Frost is most likely to damage fruit from the middle of April to the end of May and during the month of October.

The general conditions which precede frost are increasing barometer, falling temperature, low humidity, light west to northwest winds, and clearing or clear weather.

CLEVELAND, OHIO.

Precipitation is usually preceded thirty-six to forty-eight hours by southeast to southwest winds and falling barometer, and the barometer generally falls to 29.80 or below in spring and summer, and to 29.90 or below in autumn and winter before precipitation begins. In all seasons, when the barometer falls rapidly, with wind backing from south to brisk northeast, the precipitation is likely to be copious.

There is usually an increase in relative humidity following a dry period, which continues irregular up to a few minutes before the beginning of rain; the increase is then rapid during a period of perhaps ten or fifteen minutes. The moisture of the air is not considered in itself an aid in forecasting.

Very little reliance can be placed in any season on the appearance or formation of cirrus or cirro-stratus clouds as indicators of precipitation. The cirrus and cirro-stratus clouds which appear are generally observed moving from southwest or west-southwest.

High winds of spring are from southwest to northwest with rising barometer; of summer from west to north with rising barometer, and frequently from southeast to south with falling barometer; of autumn and winter from southwest to northwest with rising barometer.

In all seasons abnormally high temperature is attended by southeast to southwest winds, while a change from abnormally low temperature, or from warm to cold, sets in with a shift of wind from the south to the northwest or north. The lowest temperatures during the colder half of the year are not registered until the wind is again from the south quadrant.

Spring frosts as early as April 5 in advanced seasons, but usually not until May 1, are likely to damage fruits or other crops. In autumn frosts as early as September 20 will damage crops. From September 20 to November 20 is the period when warnings of frost or freezing weather are most desired by vegetable and fruit growers.

The warnings of severe freezes in November are greatly valued by truck gardeners.

At 8 a. m. of the day immediately preceding frost the conditions in the majority of cases are as follows: Pressure above normal and increasing, temperature decidedly below normal as a rule, relative humidity variable but generally above the normal, wind direction irregular, but southerly winds are most frequent; force of wind varying from gentle to fresh; clear weather is found in about 50 per cent of the cases examined, and cumulo-stratus clouds are more frequent than any other type.

COLUMBIA, MO.

Precipitation is usually preceded twelve to twenty-four hours by south to southeast winds and falling barometer, and the barometer generally falls to 29.90 or below before rain begins. In summer and autumn, however, rain usually begins with the barometer "on the turn" from falling to rising.

There is usually a decrease in relative humidity one to two days preceding precipitation, although an increase is sometimes observed.

Cirro-stratus clouds general, thickening, and followed by alto-stratus and alto-cumulus, often precede rain or snow in autum and winter. In about 33 per cent of the instances noted, precipitation is preceded one to two days by cirro-stratus clouds moving from the west in spring, summer, and autumn, and from the northwest in winter.

High winds are usually from the northwest with rising barometer in spring and autumn, from the west in summer, and from southwest to northwest in winter.

In all seasons the highest temperatures accompany southerly winds, and periods of abnormally low temperature are attended by northwest winds.

Frost is most likely to damage fruit or other crops from March 20 to April 30 and from September 15 to October 15.

Frost is usually preceded by high barometer, falling temperature, normal or low humidity, west to north winds, and clear or clearing weather.

COLUMBIA, S. C.

In spring precipitation is preceded ten to twenty hours by northeast to southeast winds and falling barometer; in summer, six to twelve hours by southeast winds and moderately low barometer, and in autumn and winter, twelve to forty-eight hours by northeast winds and falling barometer. In all seasons the barometer usually falls to 30 inches or below before precipitation begins.

In spring and winter relative humidity increases twelve to twenty-four hours before precipitation, while in summer and autumn there is a decrease in relative humidity twelve to twenty-four hours before rain, followed by an increase.

Cirrus or cirro-stratus clouds are almost invariably observed before general storms, but not before local storms in spring and autumn, and they appear ten to twenty-four hours before rain begins, moving from the west or northwest; in summer clouds of this class are seldom observed; in winter cirrus or cirro-stratus clouds, moving from the northwest, are often observed eight to twenty hours before rain. In summer and autumn low, small cumulus clouds hanging over the river early in the morning are a sure sign of rain before night; in autumn low, moderately or fast moving stratus, dark colored, and of dense texture, forerun rain.

Late in February and early in March, after an abnormally warm winter, or late in March and early in April after a normal or moderately cool winter, or late in April or early in May after an abnormally cold winter, frost will damage fruit. Truck is subject to damage by frost from February to May; strawberries in March and April; corn and cotton late in April or early in May, and cotton in October.

The general conditions which precede frost are rising pressure, low humidity, and light winds.

COLUMBUS, OHIO.

In spring and autumn precipitation is most frequently preceded by southeast winds and falling barometer, and the barometer generally falls to about 30 inches before rain begins; in summer southerly winds and falling barometer precede rain, and rain usually begins just after or "on the turn" from falling to rising barometer; in winter southwest winds and falling barometer usually precede precipitation, and the barometer falls on an average to about 29.85 inches before rain begins.

The relative humidity seems to change very little until nearly the time of the beginning of rain; sometimes it is lower than usual, and, in some instances, a slight increase is shown several hours before rain begins. Increases in relative humidity that have been noted are invariably at the beginning or early in the rain period. There seems to be a decidedly high humidity at the beginning of rain, which becomes less as rain continues. If the humidity is high and the temperature fall promises to be decided, the rainfall is usually heavy.

While cirrus clouds are nearly always observed before rain, and cirro-stratus clouds have been marked before a heavy rainfall, the cirrus clouds are so frequently noted when no rain follows that they are not considered of much value in forecasting. Strato-cumulus clouds are usually followed by rain in ten to eighteen hours; cirrus and cirro-stratus clouds have been observed forty-eight hours before rain, and again rain has occurred within twelve hours after their appearance. The average interval is estimated at thirty-six hours.

Cirro-stratus clouds are observed moving from the west in spring and autumn, from west to southwest in summer, and from west to northwest in winter. The following special characteristics of cloud formations often presage rain: Upper clouds of the cirrus type are followed by haze and very delicately fibered cirro-cumulus. All classes of cirrus clouds are noted, and their movements are usually rapid; alto-stratus follow, and their direction is most favorable for rain when they are from south to southwest. The varied movements and marked character of each type of clouds in the order observed presage rain.

In summer high winds usually occur with falling barometer or barometer "on the turn" from falling to rising, and are easterly when the barometer is falling and westerly when it is rising. The high winds of summer, autumn, and winter are southwest to northwest with rising barometer.

During periods of abnormally high temperature the wind is from the southeast to south in spring, from southwest in summer, from south in autumn, and from south to southeast in winter. During periods of abnormally low temperature the wind is from north to northwest in spring and autumn, from northeast to northwest in summer, and from southwest to northwest in winter.

Frost is likely to damage fruit after April 15, and after about May 15 it will injure garden crops and field corn. In the fall late garden crops and field corn are injured as late as September 25 to October 1, and injury is sometimes caused to late potatoes as late as October 15. The conditions favorable to frost are high and nearly stationary barometer, low temperature, no clouds, very light winds, and low humidity. In several instances, however, heavy frost, with temperature at freezing or below, did very little damage to fruit in blossom, and this fact was attributed by local farmers to the dryness of the air.

CONCORDIA, KANS.

In spring rain is preceded twenty-four to thirty-six hours by southeast winds and falling barometer; in summer and autumn rain is preceded thirty-six to forty-eight hours by south to southeast winds and falling barometer, and precipitation begins when the barometer is "on the turn" from falling to rising; in winter precipitation is preceded twelve to twenty-four hours by falling barometer. In summer and autumn the barometer is nearly stationary for about forty-eight hours, then falls rapidly during the twelve hours immediately preceding rain, and rises rapidly during rain and for several hours after rain begins.

In spring and autumn the relative humidity increases as rain approaches; in summer very little moisture precedes rain; in winter, if winds are northeast, increasing relative humidity indicates snow.

In spring cirrus clouds, moving from the southwest, appear forty-eight hours in advance of rain, and before rain begins are followed by alto-cumulus and alto-stratus clouds in summer. Cumulus clouds sometimes precede rain, but rain is always preceded by strato-cumulus clouds in this season. In autumn cirrus clouds moving from the southwest appear thirty-six hours in advance of rain and are followed by alto-stratus clouds. In winter a few cirrus clouds, moving from the southwest, sometimes appear twenty-four to thirty-six hours in advance of precipitation and are followed by alto-stratus clouds.

In spring high winds occur from the south and southeast, with falling barometer; in summer from south to southwest with falling, and from northwest with rising barometer; in autumn from south with falling, and from northwest with rising barometer; in winter from north and northwest with rising barometer.

During periods of abnormally high temperature the winds are from south to southeast in spring and winter, from south to southwest in summer, and south in autumn. During periods of abnormally low temperature the winds are from north to northwest in spring and winter, from north to west in summer, and from northwest in autumn.

Frost is most likely to damage fruit or other crops in April and the early part of May.

In spring and autumn the conditions favorable for frost are barometer normal or above, temperature below normal, humidity normal or below, light winds, clear weather, or rapidly decreasing cloudiness.

CORPUS CHRISTI, TEX.

In spring rain is usually preceded about twenty-four hours by backing east and northeast winds and barometer "on the turn" from falling to rising, and rising. In this season a steady fall in barometer with wind from the southeast means clearing weather. In summer easterly winds backing from southerly precede rain twenty-four to thirty-six hours, and rain usually begins after the barometer has fallen to 29.90 or 30 inches and begins to rise. After periods of low barometer in summer, showers follow on the rise if the winds are backing; if the barometer is 29.80 and falling no rain occurs until the rise begins; when the barometer is above 30 and fluctuating thunderstorms and heavy rains are likely to occur. In autumn rain is generally preceded about twenty-four hours by east to northeast winds and rising barometer, except in November, when rain follows falling barometer and winds north and veering. In winter northeast winds usually precede rain twelve to twenty-four hours with barometer falling; rain also occurs with rising barometer and backing southerly winds. In all seasons the barometer falls to a height of 29.90 to 30 inches before rain begins.

In spring and summer there is a notable decrease in relative humidity thirty-six to forty-eight hours before precipitation begins, but nearly all rainfall occurs with relative humidity between 80 and 90 per cent. In autumn and winter the humidity increases twelve to twenty-four hours before precipitation to about 90 per cent in autumn and to 80 per cent or above in winter.

Cirrus or cirro-stratus clouds do not to any extent indicate precipitation when moving from the northwest, west, or southwest, but rain follows in thirty-six hours when these clouds are observed moving from the north. In summer cirrus and cirro-stratus clouds from the south and southeast are sometimes followed within thirty-six to forty-eight hours by rain. In autumn and winter cirrus or cirro-stratus clouds from the south are almost invariably followed by rain within thirty-six hours. In summer lower cumulus, changing shape and color, with rising barometer, presage rain.

In spring the highest winds usually occur from the southeast, with falling barometer; in summer from the northeast with falling, and from north to west with rising barometer; in autumn from north and northwest with rising barometer, except in September, when they come from east to northeast with falling barometer; in winter from the north and northwest with rising barometer.

During periods of abnormally high temperature the winds are usually from the southeast in spring, except sometimes from the west in May; in summer the winds are westerly; in autumn the warm winds are westerly in September and October and southeasterly in November; the warm winds of winter are from the southeast. During periods of abnormally low temperature the winds are from north to northeast in spring and autumn, from easterly in summer, and from northeast to northwest in winter.

Frost is most likely to damage fruit or other crops from November 15 to March 20. Vegetables are raised during all the winter months when there is sufficent rainfall; after the 15th of January is the most critical time, however. Shipping to northern markets begins in February and continues to about the last of April.

The general conditions most favorable to frost in spring and autumn are high barometer, temperature 38° and below, humidity 70 per cent and under, clear weather, brisk north to westerly winds, subsiding at sunset; in winter high barometer, temperature 45° and below, relative humidity 70 per cent and under, and clear weather. Frost is not a frequent occurrence at any season; it generally follows after the low barometer area has crossed the meridian twenty-four to thirty-six hours, and the center of the high barometer area is west and south of the Missouri River. A gathering of cirro-stratus or alto-stratus clouds in the west is an indication of a rapidly diminishing high barometer area, and frost is not likely to occur at such times.

DAVENPORT, IOWA.

Precipitation is usually preceded about twenty hours by northeast to southeast winds and falling barometer, and the barometer generally falls to 29.90 in spring, 29.95 in summer and autumn, and 30 in winter before precipitation begins. In summer, however, showers are often preceded by southeast to southwest winds and come "on the turn" of the barometer from falling to rising. With a falling barometer rain usually begins with a pressure of about 29.95 inches, though during the passage of very energetic storms the beginning of rain is often delayed until the barometer has nearly reached its lowest point, and sometimes until about the time it begins to rise. With a rapidly rising barometer after the passage of a storm of decided energy rain usually ceases before the barometer has risen to 29.90 inches. Before summer thunderstorms the barograph trace is, in most cases, very jagged and irregular.

There is usually a decrease in relative humidity about eighteen hours before precipitation begins. At times, however, there is an increase in humidity two to six hours before rain falls.

During the warm season of the year, from late spring to early autumn, cirro-stratus clouds are generally observed along the western and southwestern horizon twelve to eighteen hours before the beginning of rain. No particular cloud formation that can be relied upon as a guide has been observed during the cold season. During the warm season before a thunderstorm which occurs in the following late afternoon, evening, or night banks of cirro-stratus clouds generally extending upward only a few degrees are almost invariably noticed along the southwest and western horizons in the morning. A peculiar hazy condition of that portion of the sky is also noticed at such times.

During periods of abnormally high temperature the prevailing winds are from the east, southeast, and west in spring; from south to southwest in summer and autumn, and generally from the southwest in winter. During periods of abnormally low temperature the winds are from northeast to northwest in spring and summer and from northeast to northwest in autumn and winter.

Frost is likely to prove injurious to fruit or other crops after May 1 and before October 1. Late frosts which occur after May 1 are likely to damage fruit trees or early garden truck; and early frosts occurring before October 1 would be likely to prove injurious to garden truck. Cereals are generally out of danger by the middle of September.

The heavy frosts of spring are usually preceded by a rising or high pressure, relatively low and falling temperature, low humidity, light west and north winds, and clear skies. In early autumn frosts are preceded by nearly the same conditions as those noted for spring.

DENVER, COLO.

In all seasons precipitation is generally preceded several hours by northeast winds, and begins with rising barometer. The usual height of the barometer observed at the beginning of precipitation is 29.90 in spring, 29.95 in summer and autumn, and about 30.15 inches in winter.

The moisture of the air is not an indicator of approaching precipitation, and an increase or decrease in relative humidity is observed occasionally only an hour or two in advance of precipitation.

During the colder half of the year cirrus clouds from the west are generally a reliable indication of a low barometer area in the northwest and rising temperature. A long and narrow bank of stratus clouds above the mountains in the west at about 30° altitude is indicative of chinook conditions within twenty-four hours. In summer cumulus clouds on the mountains early in the morning rapidly develop thunder-storm conditions if pressure distribution is favorable to northeast winds.

The highest winds of spring and autumn are from northwest, with rising and from southwest with falling barometer; and of winter from northwest with rising barometer.

Westerly winds prevail during periods of abnormally high temperature. During periods of abnormally low temperature the winds are northeasterly during the day and southerly at night.

Frost is most likely to damage fruit or other crops between April 10 and September 30.

The conditions which usually precede frost are high barometer, temperature below 44°, humidity above normal, light precipitation, light winds, and clearing weather, with no clouds when frost occurs.

DES MOINES, IOWA.

Precipitation is generally preceded twelve to twenty-four hours by southeast winds and falling barometer, and in spring, summer, and autumn the barometer usually falls to 30 or below before precipitation begins. In winter precipitation often begins when the barometer has fallen to 30.10. During fair weather, which has prevailed for several days, a sudden rise, followed by falling barometer, usually indicates the near approach of rain, and when the barometer begins to rise during a general rain or snowstorm clearing weather will soon follow. Summer showers often occur without an apparent regard to barometric movements.

It has been found that, as a rule, the relative humidity increases slightly before the beginning of rain; at other times there is a decided increase in humidity at least twelve hours before rain; while at times no increase in the moisture of the air has been noted until after precipitation has begun.

Cirrus and cirro-stratus clouds moving from the northwest are sometimes observed twelve to twenty-four hours before precipitation. The most characteristic cloud formation that presages precipitation is a peculiar and distinctive type of cirro-stratus, frequently called sheet cirro-stratus. These clouds present a hazy appearance, cover a small area, and usually are of short duration. The type of cirro-stratus known as "mackerel sky" also presages rain, but this type is not so frequent nor so well defined as in the Atlantic coast States. Cumulus clouds frequently precede showers in summer, and in winter snow is often preceded by cirro-cumulus clouds.

South to southwest winds prevail during periods of abnormal heat and northwest to north winds during periods of abnormal cold.

Frost is likely to injure fruit or other crops from April 20 to May 25, and from August 20 to September 15. In all seasons frost is generally preceded by rising, or high stationary barometer, temperature 41° to 54° at the morning and 50° to 58° at the evening observation of the preceding day; relative humidity high at the preceding morning and low at the preceding evening observation; wind northwest to northeast; and generally clear weather at the observation of the preceding evening.

DETROIT, MICH.

Precipitation is usually preceded ten to twelve hours by southeast to southwest winds. In summer the barometer generally falls to 29.80 before rain begins, in spring and autumn to 29.85, and in winter to 29.90. In spring rain begins with falling barometer, just after the turn from rising to falling; in summer with stationary or falling barometer; and in autumn and winter with falling barometer. Snow flurries or light showers sometimes occur twelve to twenty-four hours after the barometer begins to rise during clearing weather. A rapid fall in the barometer with east to south winds immediately precedes precipitation. When the barometer rises slowly precipitation usually continues until the barometer reaches 29.95; in winter, however, the weather will clear shortly after the barometer begins to rise, especially if the pressure has been quite low.

During the summer months the relative humidity has been observed to be abnormally low ten to fourteen hours before thunderstorms, especially in the afternoon when thunderstorms occur the following morning. In all other seasons no connection has been noted between atmospheric moisture and approaching precipitation.

The only special rain indication noted in connection with clouds is a peculiar formation of cirro-cumulus clouds during spring, autumn, and winter, when clouds of this class that present a creamy appearance indicate rain or snow within about twelve hours. In spring, autumn, and winter cirro-cumulus clouds at night in long lines, frequently with halos, indicate rain or snow. The movement of these clouds is usually moderately rapid. Cirrus and cirro-stratus clouds move from the west, but the interval between their appearance and the beginning of precipitation has not been observed.

The high winds of spring are from northeast with falling barometer, and from southwest to west with low and rapidly rising barometer; of summer from southwest with rising barometer; of autumn from southwest to west with rapidly rising barometer; and of winter from northeast to east with rapidly falling barometer, and from southwest to west with rapidly rising barometer.

During periods of abnormally high temperature the winds are usually from south to southwest. In spring the cold winds are from northwest to northeast, in summer from northeast to east, in autumn from west to northwest, and in winter from southwest to west, and on rare occasions, from the northeast.

Frost is likely to damage fruit or other crops from April 15 toMay 15, and from September 1 to 20. Frost is usually preceded by barometer above 30 and rising, an indicated temperature fall to between 30° and 35°, relative humidity 70 to 75 per cent; in spring northwest to northeast winds, cumulo-stratus moving rapidly in the afternoon, and evening clear; in autumn light westerly winds and no clouds.

DODGE CITY, KANS.

In all seasons precipitation is generally preceded ten to eighteen hours by southeast to northeast winds and falling barometer, and precipitation begins on or after the turn of the barometer from falling to rising. As a rule the barometer falls to about 29.85 in spring and summer to 29.90 in autumn, and to about 30.05 in winter before precipitation begins.

The observer has not noted the relation, if any, that exists between atmospheric moisture and approaching precipitation.

Cirrus and cirro-stratus clouds move from the west, but the observer has not noted the extent to which they forerun precipitation. Clouds moving rapidly from the southwest when the barometer is on the turn from rising to falling have been observed to precede rain.

The warm winds of spring and summer are from southeast to southwest, and of autumn and winter from southeast to south. In spring the cold winds come from the north and northwest, and during the balance of the year from northeast to northwest.

Frost is most likely to damage fruit or other crops in April and May. Heavy frost is usually preceded by rising barometer, low humidity, few clouds, and light west to northwest winds.

DUBUQUE, IOWA.

Southeast winds and falling barometer precede precipitation twelve to twenty-four hours in spring and autumn, and often for a period of forty-eight hours in winter. In summer southerly winds usually precede rain about twelve hours, and rain begins on the turn of the barometer from falling to rising. In all seasons the barometer generally falls to 29.90, or below, before precipitation begins.

An increase or decrease in relative humidity has not been observed to precede precipitation, except in winter, when an increase in atmospheric moisture, with rising temperature, is a sure indication of precipitation.

Cirrus or cirro-stratus clouds moving from the west forerun precipitation about twelve hours in spring and autumn, and twenty-four to forty-eight hours in winter. In summer cirrus or cirro-stratus clouds seldom appear. The most common forms of clouds that presage rain in spring and autumn are hazy cirro-stratus in spring and autumn, cumulus and cumulo-stratus in summer, and thickening stratus in winter.

The warm winds of this locality are from south to southeast in spring, autumn, and winter, and from south to southwest in summer. The cold winds of all seasons are from west to northwest.

Frost is most likely to damage fruit or other crops in the latter part of April, in May and September and early in October. Heavy frost is generally preceded by low and rising barometer, falling temperature, high and decreasing relative humidity, and clearing weather.

DULUTH, MINN.

Precipitation is usually preceded fourteen to eighteen hours by northeast winds in spring, summer, and autumn, and by southerly winds in winter. The barometer generally falls to 29.90 in summer and autumn, to 30 in spring, and to 30.05 in winter before precipitation begins. In summer with northeast surface winds, clouds before and during rain are frequently from the southwest.

The relative humidity generally increases ten to fifteen hours before precipitation begins to 80 per cent, or above, in spring and winter, and to 85 per cent, or above, in summer and autumn.

Cirrus or cirro-stratus clouds moving from the west in spring, summer, and winter, and from west to northwest in autumn generally precede precipitation about thirty-six hours and, occasionally, three to five days. Cirrus, cirro-stratus, cirro-cumulus, and alto-stratus from westerly and northerly directions in all seasons usually indicate precipitation within six to forty-eight hours (low and high average). Sometimes only a narrow band of cirro-cumulus is an excellent index of rain, especially in summer. In spring and autumn lower clouds from southerly to northeasterly presage rain; in summer heavy cumulus, strato-cumulus, or stratus in the west or southwest, or moving from southwest or northeast, indicate rain; in winter dull, lead-colored stratus or strato-cumulus clouds from a southerly direction, or from northeast, when the lake is open, forerun precipitation. Lunar halos are generally followed by precipitation in eighteen hours, and solar halos in about twenty-four hours on an average.

In all seasons the warm winds are from southwest, except in December, when abnormally high temperature sometimes has surface winds from the northeast. During periods of abnormally low temperature the winds are northeast to southeast in spring and autumn, northeast in summer, and west to northwest in winter.

Frost is most likely to damage fruit or other crops from May 15 to September 25. Heavy frost is usually preceded by increasing and low barometer, relative humidity, low, and increasing from about 50 to 95 per cent, decreasing southwest and north winds, temperature falling to 38° or below, and clearing or clear weather.

EASTPORT, ME.

South to east winds usually precede precipitation about twelve hours, and precipitation generally begins when the barometer has fallen to 29.85 or below.

An increase in relative humidity occurs several hours before precipitation, and 80 to 90 per cent of relative humidity indicates an early beginning of precipitation.

Cirrus or cirro-stratus clouds moving from the west often precede precipitation ten to fourteen hours in spring, summer, and autumn, and six to eight hours in winter. The clouds thus observed move rapidly and merge into stratus.

The high winds of spring and winter are from easterly with falling, and from westerly with rising, barometer; in summer and autumn high east to south winds occur with falling, and high westerly winds with rising, barometer.

The warm winds of spring are from the southwest, of summer from westerly, and of winter from south to east. The cold winds of spring are from northwesterly, of summer and autumn from south to east, and of winter from northerly.

Frost is most likely to damage crops during the latter half of April and in September. Heavy frost is usually preceded by high barometer, falling temperature, low relative humidity, and light northerly winds.

ELKINS, W. VA.

In spring, autumn, and winter southwest winds and falling barometer precede precipitation twelve to twenty-four hours, and the barometer generally falls to 30 inches or below before precipitation begins.

Summer showers are often preceded by light and variable winds, and begin on the turn of the barometer from falling to rising.

While an increase in humidity was observed to precede precipitation during the autumn and winter of 1900–1901, it can not be said that high humidity indicates rain, as frequently the humidity is high during dry periods, especially in autumn, which is the season of minimum rain frequency.

During periods of abnormally high temperature the winds are generally from a southerly quarter. The cold winds of all seasons are from west to north.

While cirrus or cirro-stratus clouds moving from the west in spring, summer, and autumn, and from the southwest in winter, have been observed generally to precede storms and give place to lower clouds, these clouds are frequently followed by dry weather during autumn.

Frost is likely to damage fruit or other crops from April 1 to June 10, and during September and October. Heavy frost is usually preceded by high pressure. At the preceding 8 p. m. observation the temperature may be as high as 60°, and the dew point considerably above 32°. North to west winds decrease in velocity to calm. Absence of clouds appears to be a most important factor, as at this altitude loss of heat by radiation takes place rapidly.

EL PASO, TEX.

No special features regarding wind directions and movements of the barometer preceding rain have been noted by the observer. Franklin Mountain, which is about 1½ miles north of station, diverts north and south winds, especially south winds, to other directions, and the wind-direction records of the station are, therefore, reported as largely the product of local causes. High velocities, as shown by the local vane, are extremely rare, although high north winds prevail at times in the vicinity.

The extent to which the moisture of the air indicates precipitation has not been observed.

During periods of abnormal heat the prevailing winds are from the northwest in spring and winter, and from east or northwest in summer and autumn. The cold winds of spring and winter are also reported as coming from the northwest, while in summer and autumn they are from east to northeast. Wind directions are, however, untrue on account of causes above referred to.

Cirro-stratus clouds are sometimes observed moving from the southwest in summer and autumn, and from west to southwest in spring and winter. No relation has been locally observed, however, between these clouds and approaching precipitation.

Frost is likely to damage vegetation in the spring, after March 15. Actual frost is so extremely rare at this station that the conditions favorable to its occurrence can not be stated. The frost records are, in fact, those of freezing temperatures.

ERIE, PA.

In the colder months precipitation is preceded by winds from either the east or south quadrants. When winds set in steadily from the east quadrants with falling barometer precipitation quickly follows. When winds set in from south to southwest, during the colder months, with falling barometer precipitation usually follows in twelve to twenty-four hours. During the warmer months rain is usually preceded twelve to twenty-four hours by south to southwest winds and falling barometer, and the barometer generally falls to 29.90 or below before rain begins. Summer showers occur with the shift of the wind to southwest and on the turn of the barometer from falling to rising.

In spring and summer the relative humidity generally decreases twelve hours before rain begins, while in autumn and winter an increase in relative humidity is observed about twelve hours in advance of precipitation. The moisture of the air is not, however, a particularly good indication of precipitation at any season of the year.

The special characteristics of cloud formation, either of kind, direction, or of speed that presage rain at this station have not been noted by the observer.

During periods of abnormally high temperature the winds are from south to west. During periods of abnormally low temperature the winds are from west to northwest. The high winds at this station usually occur with falling barometer and come from a westerly direction.

Frost is most likely to damage fruit or other crops from April 15 to May 15.

ESCANABA, MICH.

In the spring precipitation is most frequently preceded by northeast to southeast winds and falling barometer. With freezing temperature snow will begin when the wind shifts to easterly, and about the time the barometer begins to fall. With temperature above freezing the barometer falls to 30 or below before rain begins. In summer showers are preceded by southerly winds and falling barometer, and rain begins when the wind shifts to westerly and the barometer is on the turn from falling to rising. The precipitation of autumn also occurs generally under the wind and barometer conditions noted for summer. In this season, however, precipitation is preceded by southeast winds and falling barometer, and the barometer usually falls to 29.90 or below before precipitation begins. In winter precipitation is preceded either by easterly or southerly winds and falling barometer. When by easterly winds and low temperature snow begins when the winds go into easterly and the barometer begins to fall. When by southerly winds precipitation usually begins when the barometer has fallen to 29.95, or below, and is on the turn to rising, with wind shifting to westerly.

In spring, autumn, and winter there is generally an increase in relative humidity in advance of precipitation; in summer, afternoon showers usually follow high morning humidity.

In spring cirro-stratus clouds moving rapidly from the west indicate rain; the interval between the appearance of these clouds and rain is not, however, well defined. In summer cirro-stratus clouds moving from the west indicate rain within a few hours. In winter the movements of these clouds are seldom discernible. In spring when cirro-stratus are followed by alto-stratus rain soon begins; in summer cirrus soon change to alto-stratus and then to cumulo-nimbus when rain begins; in autumn cirro-stratus changes to alto-stratus and then to stratus.

Warm winds are from the southeast in spring, from southwest to south in summer, from southeast to south in autumn, and from south in winter. The cold winds of spring are from the north, of summer from north to north-northwest, of autumn from north to northwest, and of winter from northwest, decreasing and shifting to west.

Frost is liable to do damage late in the spring and early in the fall, but no fruit and very little farming produce is subject to injury, the principal industries of this section being lumbering and mining. In spring and autumn frost usually occurs with rising and high barometer, clearing weather, and low humidity.

EUREKA, CAL.

In spring, autumn, and winter southeast winds generally set in four to eight hours before rain begins. In June rain is preceded by northwest winds. As a rule no rain falls in July and August. In spring rain usually begins with the barometer about 29.90, and near the turn from falling to rising. In autumn and winter rain begins with the barometer about 29.95 and falling, or near the turn from falling to rising.

In the spring there is usually a decrease in relative humidity four to six hours before rain, and a rapid decrease four to ten hours before heavy rain. When, in this season conditions are normal, a sudden decrease in relative humidity to about 50 per cent generally indicates heavy rain, and 90 per cent of relative humidity, with clouds and high fog, is frequently followed by light rain. In autumn the relative humidity decreases two to six hours before heavy rain, but may either decrease or increase before light rain. When the humidity is very low, with cloudy weather, rain usually follows, and late in autumn steady, light rain usually falls with relative humidity, ranging from 75 to 90 per cent. In winter the relative humidity decreases four to twelve hours preceding rain, although sometimes light rain is preceded two to six hours by an increase in humidity. In this season rain usually begins with relative humidity 80 to 90 per cent, although very low relative humidity and a marked depression of the dew-point indicates rain, or wind and rain.

Cirrus or cirro-stratus clouds are seldom observed, and when they do appear move from the northwest, and sometimes, in the summer, from the west. In spring alto-stratus clouds are observed a day or more before rain, and cumulo-stratus or stratus immediately precede rain; sometimes cirro-stratus change to alto-stratus before rain, and the latter move from a westerly direction. Similar cloud forms and movements are observed in autumn and winter, and also before the infrequent rains of summer.

The high winds of this locality are usually from the northwest, with rising or high barometer; in spring and winter the high winds may come from northwest to north. Warm winds come from southerly or southeast, and cold winds from the northeast.

Peaches and cherries are likely to be damaged by frost in March and April. In the spring heavy frost is usually preceded by barometer about normal and rising, temperature about normal and falling, relative humidity increasing during the night, calm or light winds, and few, if any, clouds; in winter by high or rising barometer, temperature falling below the normal, relative humidity about 80 per cent and increasing, and light northerly winds.

EVANSVILLE, IND.

Precipitation is generally preceded by southeast to northeast winds and falling barometer, and the barometer usually falls to 29.95 or below in spring, summer, and winter, and to 30 or below in autumn, before rain begins. In spring and winter rain begins on a falling barometer, and in summer and autumn on or after the turn in the barometer from falling to rising. In spring, autumn and winter rain winds set in thirty-six to forty-eight hours and in summer eighteen to twenty-four hours before rain begins.

In spring and summer the relative humidity increases and in autumn and winter it decreases before precipitation. In all seasons the average relative humidity preceding rain is 80 to 86 per cent.

The prevailing direction of cirro-stratus clouds is from west to northwest in spring, and from west in summer, autumn, and winter. In spring cirro-stratus clouds are forerunners of rain, and strato-cumulus clouds immediately precede rain. In summer cirro-stratus are followed by alto-cumulus and strato-cumulus clouds preceding rain. In autumn, cirrus, cirro-stratus, and strato-cumulus precede rain. In winter the upper clouds merge into alto-stratus and stratus preceding rain.

During periods of abnormally high temperature the winds are from south in spring and autumn, from south to southwest in summer, and from south to southeast in winter. The cold winds of spring and winter are from the north, of summer from the northeast, and of autumn from north to northeast.

Frost is likely to damage fruit or other crops in the spring after April 1, and in the fall before October 1.

In spring frost is likely to follow rapidly rising barometer, falling temperature, increasing humidity, northwest to north winds, and a few alto-cumulus and cirro-stratus clouds. In autumn heavy frost is preceded by rising barometer, falling temperature, increasing followed by decreasing humidity, northerly winds, and clear or clearing weather.

FLAGSTAFF, ARIZ.

In all seasons precipitation is preceded by falling barometer, and the barometer generally falls to 30, or below, before precipitation begins. In spring precipitation is preceded about twenty-four hours by southwest to west winds, in summer about twelve hours by northwest to north winds, in autumn about twenty-four hours by northwest to north winds, and in winter about twenty-four hours by south to southwest winds.

There is an increase in relative humidity before precipitation, and in summer the increase is observed forty-eight hours before rain begins.

In spring, summer, and autumn strato-cumulus clouds forerun precipitation, and in winter a similar formation appears before cumulonimbus.

During periods of abnormally warm weather the wind is from north to east in spring, from west to northwest in summer, from northwest to northeast in autumn, and from east to southeast in winter. During periods of abnormally low temperature the wind is from the southwest in spring, from southwest to west in summer, from the southwest in autumn, and from southwest to west in winter. Preceding precipitation the temperature falls in summer and rises in winter.

Frost is most likely to damage fruit or other crops in May and September.

FORT SMITH, ARK.

In the spring precipitation is preceded about twelve hours by south to southeast winds and falling barometer, and the barometer falls to 29.90, or below, before precipitation begins. In summer south to southwest winds and falling barometer precede rain about twelve hours, and the barometer falls to 29.85, or below, before rain begins. In autumn southeast to northeast winds and falling barometer precede rain eight to ten hours, and the barometer falls to 29.95, or below, before rain begins. In winter precipitation is usually preceded six to eight hours by south to southwest winds and falling barometer, and precipitation begins when the barometer has fallen to 30, or below, and is on the turn from falling to rising.

In spring and summer the humidity is not a reliable indication of rain; an increase is, however, often noted in these seasons several hours before rain. Preceding rain in autumn the relative humidity increases with a warm southerly wind to about 85 per cent before rain begins. In winter the increase in relative humidity is very noticeable twelve hours in advance of precipitation.

In spring the more dense formation of cirro-stratus clouds are forerunners of rain, and they are observed moving from the west about six hours before rain begins. In summer rain is always preceded a few hours by cirro-stratus clouds moving from the southwest. In autumn, as in spring, rain is preceded by the denser formation of cirro-stratus clouds moving from the west. This is also true of the winter months, when the clouds appear about eight hours before precipitation begins.

During periods of abnormal heat the wind is from the south or southeast in spring and autumn, from the south in summer, and from the southwest in winter. The colder winds are from the northwest in spring, autumn, and winter, and from the west in summer. During the summer season the temperature preceding thundershowers, which is the form in which rains occur, becomes abnormally high about forty-eight hours in advance of rain. In spring, autumn, and winter precipitation is preceded about twelve hours by a gradual rise in temperature.

Frost is likely to damage fruit or other crops from about the middle of March through April and May. The general conditions that precede frost are as follows: In spring, high pressure, temperature about 45°, relative humidity about 30 per cent, and light northwest winds; in autumn the same as in spring, except that the relative humidity is about 40 per cent. Cirrus clouds of a fine texture are frequently noted before heavy frost.

FORT WORTH, TEX.

In spring and summer precipitation is preceded eight to fourteen hours by falling barometer and southerly winds, and the barometer generally falls to 30 or below before precipitation begins. In autumn southerly winds and falling barometer precede rain about eight hours, and the barometer usually falls to 29.85 or below and is on the turn from falling to rising before rain begins. In winter south to southeast winds usually precede precipitation, and precipitation generally begins after the turn in the barometer from falling to rising. In the case of storms that advance from northern Mexico or the Rio Grande Valley, however, precipitation is preceded by east to northeast winds, and begins with falling barometer. Except in summer a steady decrease in the barometer indicates rain. In summer a fluctuating barometer also indicates rain.

An increase in relative humidity with easterly winds indicates rain in all seasons. When the winds are from directions other than easterly a decrease in humidity sometimes precedes precipitation. Changes in the moisture of the air do not necessarily indicate rain unless the wind is from an easterly quarter.

Cirrus or cirro-stratus clouds moving from the west are often observed ten to sixteen hours before precipitation. Lower clouds moving from north to northeast precede precipitation in spring and summer, from east to southeast in autumn, and from southeast in winter.

The warm winds of spring and summer are southerly, and of autumn and winter southwesterly. The cold winds of spring are from the northwest, of summer from the southeast, and of autumn and winter from the north.

Frost is most likely to damage fruit or other crops from March 15 to April 30, and from October 1 to November 30. In spring and autumn frost is preceded by high pressure, low temperature, low humidity, and clear weather; in winter by decreasing pressure, falling temperature, increasing humidity, light north to northeast winds, and clear weather.

FRESNO, CAL.

Southerly winds and, generally, falling barometer set in six to ten hours before rain begins, and the barometer falls to 29.90 or below before the beginning of precipitation.

There is usually a decrease in relative humidity four to six hours before rain, except during the prevalence of fog. The degree of moisture near the earth can rarely be used as an indication of approaching rain.

Cirrus clouds, moving from the west, with lunar halos occasionally precede rain two to three days in spring, autumn, and winter. Choppy, honeycombed alto-stratus clouds almost invariably precede normal rains in all seasons. These clouds have a rapid movement from a southerly direction. Local showers are usually preceded by cumulus and alto-cumulus clouds on the mountain ranges.

In all seasons the warmer winds are from east to northeast, and cold winds come from a northerly direction. The prevailing winds in all seasons are from the northwest.

Frost is most likely to damage fruit or other crops from December 10 to April 15. In winter and spring heavy frost is usually preceded by high barometric pressure, falling temperature, northerly winds, high humidity, and scattered cirrus clouds. No frost occurs in summer and autumn.

GRAND HAVEN, MICH.

In spring and winter precipitation is preceded twelve to twenty-four hours by south to southeast winds and falling barometer when storms are advancing from the west or northwest; when they come from the southwest precipitation is preceded by east to northeast winds and often begins shortly after the wind sets in from these directions. Heavy snow often occurs after the wind has shifted to west and northwest following the passage of a storm and with rising barometer. Summer rains are usually preceded by southerly winds and falling barometer and begin about the time the lowest barometer is reached, or on the turn of the barometer from falling to rising. Southwest storms are, however, occasionally the cause of rain in late summer and autumn and are preceded by the same general conditions that have been noted for spring and winter storms. Except in the case of southwest storms the barometer generally falls to 30, or below, before precipitation begins.

There is usually a decrease in relative humidity twelve to twenty-four hours before precipitation begins, and an increase just before it begins, especially during the warmer months. Continued high relative humidity, unless due to fog, continued unsettled weather with rain, and clearing weather rapidly follow a decrease in relative humidity.

In spring precipitation is often preceded by cirro-stratus clouds moving from the northwest, which merge into stratus. During summer and early autumn rain is generally preceded by cirro-stratus or alto-stratus clouds twelve to twenty-four hours, which change to cumulus and cumulo-nimbus, nearly all precipitation during these seasons being in the form of thunder storms. In late autumn and winter stratus clouds prevail.

In the warmer months high winds occur with falling barometer from a southerly quarter, and with a rising barometer later when the wind shifts to west and northwest. During the colder months high southerly and southeast to northeast winds occur with a falling barometer, and high southwest to north winds with a rising barometer.

The warm winds of spring and autumn are from southeast to southwest, and of summer and winter from the southwest. The cold winds of spring come from the north, of winter from the northeast, and of summer and autumn from the northwest.

Frost is liable to damage fruit or other crops in spring after May 1, and in autumn from September 15 to October 15. Heavy frost is generally preceded by a rapid clearing of the sky toward evening, increasing or high pressure, increasing or high relative humidity, temperature falling to at least 36°, and wind diminishing to light and generally from the northeast.

GRAND JUNCTION, COLO.

The prevailing winds at this station are from the northwest in spring, summer, and autumn, and from southeast in winter. Precipitation is generally preceded by steadily falling barometer, and begins on the turn of the barometer from falling to rising. It appears that precipitation begins after an area of low barometer has passed and with the approach of the succeeding area of high barometer. As many low areas pass over this locality without precipitation no invariable rule can, however, be laid down. The barometer usually falls to 29.90 or below in spring and autumn, to 29.85 in summer, and to 30 or below in winter before precipitation begins. Owing to the topography of the section, and to the small amount of precipitation, it has not been possible to determine the ruling direction of "rain" and "dry" winds.

Beyond the fact that there is a slight increase in relative humidity before precipitation, the extent to which the moisture of the air indicates rain has not been observed; neither has there been any special attention paid to clouds, their formations and characteristics, in connection with precipitation, beyond the fact that cirrus clouds move from a westerly direction.

During periods of abnormally high temperature the wind is usually from the southeast; the direction of cold winds in autumn and winter is also given as southeast, while those of spring and summer are from the northwest.

Frost is most likely to damage fruit or other crops from April 1 to May 15. Heavy frost is preceded by rising barometer, wind shifting to northwest, temperature about normal, and relative humidity about or slightly above normal.

GREEN BAY, WIS.

In all seasons precipitation is preceded by falling barometer, and the barometer falls to 29.90 or below before precipitation begins, except in winter, when precipitation often begins with the barometer about 29.95 to 30. In spring and autumn precipitation is generally preceded by southeast winds, in summer by southeast to southwest winds, and in winter by southeast to northeast winds, the winds setting in from these directions twelve to twenty-four hours before precipitation begins.

In spring and winter there is a slight decrease and in summer and autumn a slight increase in relative humidity before precipitation, the changes being noted for a short period only before the beginning of precipitation.

Beyond the fact that cirrus clouds move from the southwest and west, no note has been made of characteristic cloud forms that precede precipitation at this station.

The warm winds of all seasons are from the south. The cold winds of winter and spring are from the southwest, of summer from the north, and of autumn from the west.

Frost is likely to damage fruit or other crops after May 15 and before September 20. Heavy frost is usually preceded by high barometer, moderately low humidity, northerly winds, and clear weather.

HANNIBAL, MO.

In spring and winter precipitation is generally preceded one to two days by east to south winds and falling barometer. In summer the same general conditions of wind and barometer precede rain, except in the case of showers and thunderstorms, when rain begins about or after the turn in the barometer from falling to rising. Autumn rains are usually preceded one to two days by easterly winds and falling barometer. In spring, summer, and autumn the barometer falls to 29.90 or below, and in winter to 30 or below, before precipitation begins. Rapidly falling barometer during the night or forenoon, and often in the afternoon, indicates rain, and the earlier the fall begins during the day the more certain rain will occur in twelve to twenty-four hours. A decided rise after such a fall indicates clearing weather.

The relative humidity usually increases, but sometimes decreases, six to twelve hours in advance of rain.

Cirrus and cirro-stratus clouds usually precede precipitation during late fall, winter, and early spring, and cumulus clouds usually precede rain during late spring, summer, and early fall. In spring and winter the prevailing direction of cirrus clouds is from west to southwest, and in autumn from the west. Cumulus clouds just above the western horizon precede thunderstorms, and the earlier they appear in the morning the more certain it is that local showers or thunderstorms will occur in the afternoon or evening of the same day; while if they do not appear until the middle of the forenoon or toward noon thunderstorms may not occur for a day or two, especially if the altitude of the clouds is great.

South to southwest winds prevail during periods of abnormal heat. The cold winds of spring are from northwest to northeast, of summer from northeast, and of autumn and winter from northwest to north. During the colder months a rapid rise in temperature after a cold period is usually followed by precipitation.

Frost is most likely to damage fruit or other crops from April 15 to May 31 and from September 1 to October 10. Heavy frost occurs with high barometric pressure, temperature near the freezing point, humidity above the normal, and light north to west winds. Heavy frost may occur with humidity below the normal.

HARRISBURG, PA.

In all seasons precipitation is usually preceded about twenty-four hours by east to south winds and falling barometer, and the barometer generally falls to 30 or below before precipitation begins. Summer showers, as a rule, begin on or after the turn in the barometer from falling to rising.

An increase in relative humidity is observed six to twenty-four hours before precipitation; on the approach of thunderstorms the relative humidity increases until the storm begins, then decreases rapidly, and increases again after the storm. Heavy frost is often followed by rain within eight to thirty-six hours.

Cirrus and cirro-stratus clouds generally indicate precipitation, and are observed moving from the west eighteen to twenty-four hours before precipitation begins. After a period of fine weather cirrus clouds are usually the first indication of an approaching storm. Cirro-stratus clouds, or clouds of a halo-forming character, indicate rain about two times in five. A low bank of dark clouds along the western horizon at sunset is nearly always followed by rain before sunrise the next morning, and generally before midnight.

Frost is likely to damage fruit or other crops from April 1 to May 10. In spring and autumn heavy frost is preceded by stationary and high barometer, falling temperature, low relative humidity, and clear or partly cloudy weather. In winter the same conditions obtain except that the relative humidity is usually high.

HAVRE, MONT.

Precipitation is preceded by falling barometer and northeast winds, and begins about the time the barometer is on the turn from falling to rising. A falling barometer, with marked oscillations, is followed by precipitation, and a sudden and marked fall in the barometer below and continuing below the normal indicates rain or snow. The period that elapses between the time the wind sets in from the northeast and rain or snow begins varies from about twelve hours to several days, the period being longer, as a rule, in the warmer months.

The expression "It feels like rain" is especially applicable to the climate of this section, and many rains are preceded by a "softness" of the atmosphere which may be due to increased humidity.

Cirro-stratus clouds are, to an extent, forerunners of rain. In autumn and winter cirro-stratus clouds that produce well-defined halos are often observed moving from the west twelve to twenty-four hours in advance of precipitation. The cirro-stratus are the only clouds that appear to presage precipitation before the rain-bearing clouds actually appear.

In the colder months precipitation begins with rising temperature, and in the warmer months rain begins with falling temperature or with temperature on the turn from rising to falling.

During periods of excessive or unseasonable heat the prevailing winds are from the southwest. The cold winds of spring are from the northeast, of summer from the north, and of autumn and winter from the north.

Frost is likely to damage crops from June 1 to August 15. The conditions favorable to the occurrence of heavy frost are barometer above the normal, temperature about 36°, humidity low, clouds, if any, dissipating, and wind light.

HELENA, MONT.

The heavy rains of May and June are usually preceded twelve to twenty-four hours by northeast to east winds and falling barometer; they sometimes begin on a falling barometer, but generally after the turn in the barometer from falling to rising. In summer southwest winds precede rain twelve to thirty-six hours, and in autumn and winter precipitation is preceded about twelve hours by southwest to northwest winds; in these seasons also the barometer falls before precipitation, but precipitation seldom begins until after the turn from falling to rising barometer. In winter the barometer generally falls to 29.90 or below before precipitation begins; in the other seasons the depression of the barometer preceding precipitation is greater.

Generally no rain accompanies a "chinook" condition, except possibly a very light shower at the beginning. "Chinooks" generally occur on a rapidly rising barometer, or on a rapidly fluctuating barometer; these conditions indicate cloudy weather without rain. An area of low barometer over Idaho or Utah on the western slope with an area of high barometer moving southward along the eastern slope indicates a decided fall in temperature and heavy snow, especially during the autumn.

Very little relation has been observed between atmospheric moisture and rain, and in summer the atmosphere is often very dry during the twenty-four hours preceding precipitation.

No relation has been observed between cirrus and cirro-stratus clouds and rain. Cirrus clouds are generally observed moving from a westerly direction, with an inclination to move from the south of west in summer and from north of west in winter. Cirrus and alto-stratus clouds, when in a well-defined bank, indicate the approach of an area of low barometer, or storm. In winter cold waves are indicated by the lower clouds. Streams of fog will often be seen pouring down the ravines and canyons 25 miles to the northward twelve to twenty-four hours before snow at Helena. In spring, autumn, and winter alto-stratus, cumulus, and stratus clouds all indicate precipitation when other conditions are favorable. In summer cumulus clouds are forerunners of showers.

The warm winds of all seasons come from the southwest, and the cold winds of winter from north to northwest. Chinook conditions during the summer are of short duration, and when they occur are accompanied by lower temperature instead of higher, as in winter.

Frost is likely to damage vegetation from April 1 to May 30, and from August 15 to September 30. Heavy frost is preceded by high barometric pressure, temperature below 36° at 8 p. m., dew-point near 32°, clear weather, with very light wind or a calm.

HURON, S. DAK.

Precipitation is preceded twelve to twenty-four hours by southeast to east winds and falling barometer, and in spring, summer, and autumn begins when the barometer has fallen to 29.90 or below, and about the time of the change from falling to rising barometer. In winter precipitation sometimes begins some hours before the barometer reaches its lowest reading, and at other times it begins on or after the turn from falling to rising; in this season precipitation seldom begins before the barometer has fallen to 30 or below. Rain or snow that occurs with rapidly rising barometer is usually of short duration. Slowly falling barometer, with wind backing from southeast to east and northeast (storm center in the west or southwest and high pressure in the northeast), almost invariably indicates precipitation, especially in spring and autumn, and some of the heaviest rain and snow storms are preceded by these pressure conditions. A steady southwest wind indicates clearing or continued fair weather.

In spring there is usually an increase in relative humidity six to twelve hours before precipitation, especially in cases where the precipitation continues long. Before summer showers, when the temperature is high and increasing, the relative humidity decreases; at other times the relative humidity increases before summer rains. Autumn rains are generally preceded six to twelve hours by increasing relative humidity, especially in the cases of rains that occur late in the day or at night. With abnormally high temperature winter precipitation is preceded six to twelve hours by increasing relative humidity.

In the spring the prevailing movement of cirro-stratus clouds is from northwest to southwest, northwest predominating; in summer and autumn from southwest to west, southwest being most frequent; and in winter from northwest to west, northwest being the direction most frequently noted. In instances where these clouds are followed by precipitation, rain or snow occurs six to twelve hours after their appearance. In spring, autumn, and winter cirro-stratus and alto-stratus nearly always precede rain or snow, but are often present when no rain or snow occurs. In summer cirro-stratus and strato-cumulus nearly always precede rain, but often appear when no rain follows.

Warm winds are from south to southeast; the "hot winds" of summer are, however, usually most intense with wind veering from south to southwest. The cold winds of winter come from northwest, veering to north.

Fruit and vegetables are likely to be damaged by frost from April 20 to September 20; wheat, oats, barley, and rye from May 1 to August 1; corn and flax from May 1 to September 20. Heavy frost is preceded by high barometer, low evening humidity, with temperature about 50° and falling, northerly winds becoming light, and clear or clearing weather.

INDEPENDENCE, CAL.

In spring, autumn, and winter precipitation is preceded ten to twenty hours by south winds and falling barometer, and the barometer falls to about 29.80 inches in spring and autumn, and becomes stationary before precipitation begins. In winter precipitation begins with the barometer about 29.80 and falling. In summer rain is preceded by southeast winds and begins when the barometer has fallen to about 29.80 and is stationary.

There is almost invariably a decrease in relative humidity two to twelve hours preceding rain, a few exceptions being noted in July, August, and September. On account of the peculiar configuration and topography of the country 100 miles to the north and south, together with the desert-like character of the entire valley, broken here and there only by very limited oases, the air is extremely dry up to the beginning of precipitation, and the rains are paradoxically called by the inhabitants "dry rains." The housewives do not take in their wash clothes from the lines on account of a rain storm, knowing by experience the rapidity of evaporation even during the time precipitation is falling. This is true of all storms, except the Sonoras, when the whole valley is filled with moisture-laden clouds. The Sonoras occur too seldom to furnish material for investigation.

Cirrus or cirro-stratus clouds moving from the northwest are sometimes observed two to three days before precipitation. Strato-cumulus clouds moving from the west and south in spring, from the south in summer and autumn, and from the southwest in winter precede precipitation.

The warm winds of all seasons blow from the northwest, and also the cold winds, except in summer, when the cool winds are from the southeast. In fact northwest winds prevail, except preceding precipitation.

Fruit or other crops are likely to be damaged by frost from September 21 to October 30, and from March 18 to May 28. In the spring almonds, apricots, and early blossoming fruit, particularly almonds, apricots, and very early vegetables, are frequently damaged, none totally, however, and peaches are occasionally injured. In the fall late-maturing vegetables, such as tomatoes, peppers, potatoes, late corn, and water melons, are subject to slight damage. In spring and autumn heavy frost is preceded by high and stationary barometer, low variable temperature, low humidity, cirro-stratus clouds, and north to northwest winds, and generally occurs after rain.

ITHACA, N. Y.

In spring, summer, and autumn precipitation is preceded twelve to forty-eight hours by southeast winds and falling barometer, and the barometer generally falls to 29.90, or below, in spring and summer, and to 29.95, or below, in autumn before precipitation begins. In winter southerly winds precede precipitation, but the winds shift more quickly and the signs of precipitation are not so well defined as in other seasons; precipitation begins in this season with a falling barometer and when the barometer has fallen to 30 or below. On account of the position of this station on the hillside and above the lake, diurnal winds are noticeable, especially during the warmer months. When not influenced by passing storms these winds come as a gentle east to southeast breeze by night and by day a northwest wind having a velocity two or three times greater than the day breeze. When, instead of shifting to the northwest in the early morning, the wind continues from the southeast and begins to increase in force, the approach of a storm is indicated. While rain begins most frequently with falling barometer, the heaviest rainfall often comes, especially in the warmer months, after the turn in the barometer from falling to rising.

Richard's registering hygrometer shows that in spring and summer the humidity sometimes decreases before rain but increases rapidly after rain begins; in spring rain begins with relative humidity from 50 to 98 per cent, and in summer it may be as low as 50 per cent one hour before rain begins. In autumn the effect of day and night seems greater than the influence of passing storms, and rain will begin with relative humidity as low as 50 per cent one hour before rain. In winter there is usually an increase in humidity from one-half to four hours before rain, and dry snow will begin with relative humidity as low as 40 per cent.

Cirrus clouds are a reliable indication of precipitation in all seasons, but are liable to be obscured by lower clouds of local formation in the colder portion of the year. These clouds appear moving from the west in spring and winter, from the northwest in summer, and from the southwest in autumn, twenty-four to thirty-six hours before precipitation begins. Special characteristics of clouds have not been noted except in connection with cirrus clouds.

Frost is likely to damage fruit or other crops in May and September. Heavy frost is generally preceded by high barometer, low temperature and humidity, very light wind and clear weather.

JACKSONVILLE, FLA.

In spring rain is generally preceded twenty-four to thirty-six hours by southwest winds and falling barometer, and rain begins with rising barometer or when the barometer is on the turn from falling to rising. Summer rains are most frequently preceded by southerly winds and begin after the turn in the barometer from falling to rising. In autumn and winter rain is usually preceded twenty-four to thirty-six hours by northeast winds and begins while the barometer is falling or is on the turn from falling to rising. In all seasons the barometer generally falls to 30, or below, before rain begins. In summer conditions are rather sluggish and are sometimes negative in character, except two to six hours before thunderstorms when the barometer falls rapidly. During the late summer and in autumn the barometer fluctuates, rising and falling, several days in advance of the arrival of tropical storms.

There is usually an increase in atmospheric moisture twenty-four to thirty-six hours in advance of rain, the period being greater in winter than during the other seasons.

Cirro-stratus clouds usually move from southwest to west, and in summer are sometimes observed moving from the northwest. Rain follows the appearance of upper clouds in 48 per cent of the cases noted in spring, in 77 per cent of the cases in summer, in 61 per cent of the cases in autumn, and in 64 per cent of the cases in winter. Aside from the upper clouds no special characteristics of cloud formation, either of kind, direction, or speed that presage rain have been made a subject of observation at this station.

During periods of abnormally high temperature the wind is from south to southwest, except in autumn, when it is from northeast to southeast. During periods of abnormal cold the wind is from north to northwest in spring, from northeast in summer and autumn, and from west to northwest in winter. During winter abnormally high temperature is quite certain to be followed by rain within thirty-six hours. In summer high midday temperatures are followed by thunderstorms in the afternoon, and thunderstorms may be expected also when a twenty-four-hour temperature change of 4° to 6° is indicated.

Frost is most likely to damage fruit from November 1 to April 10. In spring the general conditions that precede heavy frost are, barometer usually below 30, slowly rising temperature, low humidity, and light west to north wind. In autumn the heaviest frosts occur with stationary or slowly rising barometer, with wind veering during the day to northeast and backing early in the evening to north and northwest. Sometimes the wind veers to east and south, returning to west early in the evening. The easterly winds bear moisture and hence result in heavy frost. Frost is rarely heavy with the coldest weather;

the air is too dry. (It is difficult to reconcile the observer's statements of "low humidity" and "of moisture bearing easterly winds preceding heavy frost.")

JUPITER, FLA.

In spring rain is generally preceded about twelve hours by southerly winds and falling barometer, in summer about twenty-four hours by northeast to southeast winds, in autumn about twelve hours by northeast winds, and in winter about six hours by easterly winds. In summer rain begins when the barometer is near the highest or lowest point, except when tropical storms are approaching, when the barometer falls. In autumn the barometer falls slowly before and rises rapidly after rain. In winter rain begins shortly after the barometer begins to fall, with easterly winds.

In all seasons the relative humidity decreases twenty-four to thirty-six hours before rain, and increases during the twelve hours preceding the beginning of rain. Unusually high or low relative humidity indicates approaching rain in about 50 per cent of the cases noted.

Cirro-stratus clouds move from the west in spring and winter and from the southwest in summer and autumn. In spring the upper clouds appear to bear very little relation to rain. In summer and autumn cirrus clouds indicate, to a small extent, conditions favorable to thunderstorms. In winter cirrus clouds, and stratus clouds moving from southeast to south, indicate rain.

The high winds of spring come from the northeast with rising and from the southeast with falling barometer; of summer from west to north with rising and from southeast to southwest with falling barometer; of autumn from southwest to northwest with falling barometer; and of winter from southwest to northwest with rising barometer.

During periods of abnormally high temperature the wind is from the southeast to south in spring, from southwest in summer, from east to southeast in autumn, and from south in winter. During periods of abnormally low temperature the wind is from northwest in spring and autumn, from north to northeast in summer, and from northwest in autumn.

Frost is destructive to the fruit and vegetable interests of this section, but the greatest damage results from frosts that occur in the spring. The general conditions that precede heavy frost are rapidly rising barometer, after an area of low barometer has passed, falling temperature for thirty-six to forty-eight hours, dew-point below 40°, diminishing west to north wind, and clear weather.

KALISPELL, MONT.

In spring and summer precipitation is preceded six to eight hours by southeast winds and falling barometer, and the barometer falls to 29.85 or below and begins to rise before precipitation begins. In autumn and winter precipitation begins some hours after the wind has shifted to west or northwest and after the turn in the barometer from falling to rising. After precipitation begins the barometer again falls.

The relative humidity increases, on an average, nineteen hours in spring, twenty-one hours in summer, nine hours in autumn, and twelve hours in winter, respectively, before precipitation begins. In spring and summer there is usually a heavy deposit of dew before precipitation, and in autumn and winter hoar frost precedes precipitation.

Cirro-stratus clouds moving from the west are observed sixteen to twenty-four hours before precipitation. In spring and summer large cumulus or cumulo-nimbus about 20 miles southeast of station usually result in rain in this valley within twenty-four hours; clouds of this description begin to form between 9 and 11 a. m.

During periods of abnormally high temperature the wind is from the northwest in spring, summer, and autumn, and from south to southwest in winter. The cold winds of spring are from the west, of summer from the southeast, and of autumn and winter from the northwest. The high winds of all seasons come from the southwest, with rising barometer.

Frost is likely to damage fruit from May 15 to July 10, and grain from June 25 to August 1. Heavy frost is usually preceded by increasing barometer or barometer stationary and above 30, falling temperature, increasing humidity, southerly veering to light west and northwest winds, and decreasing cloudiness.

KANSAS CITY, MO.

With storms moving from southwest to northeast precipitation begins with falling barometer. Circular areas of low barometer the centers of which do not pass below central Nebraska and Iowa are seldom accompanied by rain at this station. Trough-shaped low areas usually produce precipitation on the turn of the barometer from falling to rising. In winter when a well-marked area of high barometer with low temperature crosses this section snow occurs soon after the barometer begins to fall, then ceases for a time, to begin again, possibly, on the succeeding rise in the barometer. In spring and autumn precipitation is preceded one to two days by southeast and in winter for about one day by east to southeast winds. In summer an oscillating barometer indicates a probability of thunderstorms. In all seasons a rapid fall in the barometer indicates early precipitation. Generally speaking the barometer falls to 29.90 or below in spring and autumn, to 29.85 or below in summer, and to 30 or below in winter before precipitation begins.

In spring and winter there is a decrease to a low percentage of relative humidity one to two days before precipitation; in summer and autumn the decrease is sudden twelve to thirty hours before precipitation. As an indicator of precipitation the moisture of the air is uncertain and unreliable.

Cloud aspects are misleading. Occupying, as this station does, a midcontinental position, the clouds belonging to the various cyclonic areas appear, but whether or not precipitation will follow depends on the course and intensity of the storms and the character of the season. Cirrus and cirro-stratus clouds are so frequent that the times they are followed by rain form a small percentage of the times they are observed. These clouds advance from the west in spring, from southwest to west in summer and autumn, and from west to northwest in winter. In late spring, summer, and early autumn cumulus clouds in the early morning and large cirro-cumulus during the day presage rain. In winter small cirro-cumulus clouds moving from the southwest presage, to a greater extent than any other kind of clouds, rain or snow.

During periods of abnormal heat the wind comes from southeast to southwest; the cold winds of spring and winter are from the northwest to north, and of summer and autumn from northwest to northeast.

Frost is likely to damage fruit and vegetables late in the spring, and corn and late vegetables during autumn. Heavy frost is preceded by rising barometer, temperature falling to 38° or below, light north to west winds, and a clear sky.

KEOKUK, IOWA.

In spring, autumn, and winter precipitation is preceded twenty-four to forty-eight hours by east to south winds and falling barometer. In summer the winds that precede showers come from south to southwest. The barometer usually falls to 29.90 or below before precipitation begins, except in winter, when rain or snow often begins when the barometer has fallen to about 30. A slow fall of the barometer for forty-eight to seventy-two hours indicates precipitation; a slow rise in the barometer indicates clearing and settled weather. Rapid changes in the barometer indicate early changes in the weather.

The relative humidity generally decreases about twelve hours before rain, except in winter, when it increases, and a marked decrease in relative humidity in the evening is an indication of rain in spring, summer, and autumn.

In spring cirro-stratus clouds moving from the west appear twenty-four hours before rain. In summer cirro-stratus clouds move from the southwest, and rain is preceded by increasing cumulus changing to cumulo-nimbus clouds. In autumn cirro-stratus clouds moving from the west appear twenty-four hours before rain and change to alto-stratus and then to stratus before ran begins. In winter cirro-stratus move from the northwest, and cirro-cumulus clouds appear twenty-four hours before snow. Cirro-stratus or alto-stratus moving from southwest or west and banking in the southwest or west presage precipitation. Cirrus clouds are observed during clearing weather following storms.

During periods of abnormally high temperature the wind is from south to southwest, except in winter, when it is from southeast to south. The cold winds of all seasons are from the northwest.

In September heavy frost is damaging to fruit and, if early in the month, to corn. Heavy frost is preceded by pressure above the normal, temperature falling during the evening, relative humidity between 45 and 50 per cent, light west to northwest winds, and few clouds or clear weather.

KITTY HAWK, N. C.

In spring rain is preceded one to two days by southwest winds and falling barometer, in summer one to three days by southerly winds, in autumn by northeast winds, and in winter by southeast winds. In spring rain usually begins when the barometer has reached its lowest reading, in summer on the turn in the barometer from falling to rising, in autumn, with northeast winds, soon after the turn in the barometer from rising to falling, and in winter on a falling barometer. Except with northeast winds in the autumn rain usually begins when the barometer has fallen to 30 or below in spring, summer, and autumn, and to 29.90 or below in winter.

There is an increase in relative humidity before rain, the increase being most marked in summer and winter. Much moisture at night, especially, indicates rain in from one to three days.

Cirro-stratus or cirrus clouds are sometimes observed moving from the southwest about twelve hours before rain in spring, from the south twenty-four hours before rain in autumn, and from the southwest five to eight hours before rain in winter. In summer upper clouds moving from the southeast are sometimes observed before rain.

The high winds of spring generally come from the southwest with a falling barometer, of summer from the northeast with a rising barometer, of autumn from the southeast with a falling barometer, and of winter from the northwest with a rising barometer. During periods of abnormally high temperature the wind comes from the southwest in spring, from west to southwest in summer, from south in autumn, and from south to southeast in winter. The cold winds of spring and winter come from the northwest, of summer from the north, and of autumn from the northeast.

Frost is likely to cause damage from April 10 to 30 and from October 10 to 31. Heavy frost is preceded by high barometer, temperature nearly to freezing, diminishing and light north to northwest winds, with clear weather, or a few fleecy clouds.

KNOXVILLE, TENN.

The winds at this station are prevailingly from the southwest during the spring, summer, and winter, regardless of rainfall or temperature changes. Numerous exceptions to this rule can be found, but there is no harmony among the exceptions, and no rules can be formulated. In all seasons precipitation is generally preceded by falling barometer, and the barometer falls to 30 or below in spring, summer, and autumn, and to 30.05 or below in winter before precipitation begins. In nearly all cases where precipitation begins with rising barometer it occurs in the form of light snow or light rain preceding a cold wave in winter, or a thunderstorm in summer. Immediately before clearing weather the barometer usually rises.

No particular relation between the moisture of the air and precipitation has been noted. The records of humidity at this station are too deficient to furnish satisfactory information concerning this subject.

Cirrus clouds, followed by cirro-stratus, are frequently followed by rain within twenty-four to thirty-six hours in the fall, winter, and spring, and within a few hours in summer. These clouds usually come from the southwest or west.

Frost is likely to damage fruit or other crops from March 15 to April 30 and from September 15 to November 30. Heavy frost is usually preceded by high barometric pressure, low temperature, low humidity, quiet winds, and an absence of clouds.

LA CROSSE, WIS.

In spring, summer, and autumn precipitation is preceded twelve to twenty-four hours by south to southeast winds and falling barometer, and in winter by northeast to southeast winds and falling barometer. In all seasons the barometer generally falls to 29.90 or below before precipitation begins.

There is usually an increase in relative humidity twenty-four to forty-eight hours before precipitation; at times, however, a decrease in relative humidity has been noted before rain. As the humidity is observed but once in each twenty-four hours, little weight can be given to the results obtained.

Cirrus or cirro-stratus clouds moving from the northwest are sometimes observed thirty-two to forty-eight hours before precipitation. In the opinion of the observer, clouds of any kind in any season of the year, taken alone, are of little value in weather forecasting. In spring, autumn, and winter rather low clouds with under surface broken, moving rapidly from easterly or southerly directions, and also a thin light sheet above a stratum of broken, dark fragments, indicate rain. In summer cumulus clouds of various forms preceded by arch of false cirrus precede rain.

During periods of abnormally high temperature the prevailing winds are from south to southeast. Cold winds come from the north to northwest.

Frost is likely to damage fruit or other crops from the middle of April to October 31. The general conditions that precede frost are, rising barometer, temperature 48° or below, with indications of falling to 36° or below, light north to northwest winds, and often light rain on the day preceding the occurrence of frost.

LANDER, WYO.

In spring and summer precipitation is usually preceded twelve to twenty-four hours by southwest winds, in autumn twenty-four to thirty-six hours by southwest winds, and in winter twenty-four to thirty-six hours by northeast winds. Preceding precipitation the barometer generally falls to 29.90 inches in spring, to 29.85 in summer and autumn, and to 30 or below in winter before precipitation begins. In all seasons the barometer begins to rise before precipitation begins.

The relative humidity usually increases twenty-four to thirty-six hours before precipitation. High humidity does not always indicate rain, however, and in summer and autumn rains occur with the relative humidity 50 per cent or below, and at times no rain occurs with the relative humidity near 90 per cent.

The extent to which upper clouds indicate precipitation is limited and uncertain. At times cirrus or cirro-stratus clouds moving from the west or northwest are observed twelve to twenty-four hours before precipitation. A rapid movement of stratus or strato-cumulus clouds from west or northeast generally presages rain or snow. The cloud movements at this station are generally slow.

During periods of abnormally high temperature the wind is from the southwest in spring, summer, and autumn, and the directions are about equally divided between northeast, southeast, southwest, and west in winter. The cold winds of spring are from the southeast, of summer and winter from southwest, and of autumn from northwest.

In spring frost is preceded by stationary barometer, low temperature, average humidity, northeast, southeast, west, or northwest winds, and is generally preceded by rain. In autumn and winter the same conditions obtain, except that the humidity is low preceding frost, and the wind is from southwest to northwest.

Frost is likely to damage vegetation from May 1 to June 20, and from August 20 to September 30.

LEWISTON, IDAHO.

Precipitation is usually preceded by southerly winds and falling barometer, but does not begin until the wind shifts to westerly and the barometer begins to rise. In spring and autumn the barometer generally falls to 29.90 or below, in summer to 29.80 or below, and in winter to 30 or below before precipitation begins.

During protracted periods of cloudy weather an increase in atmospheric moisture may be taken as an indication of rain. It has been observed that abnormally low humidity at 5 a. m. (the time of the morning observation) is frequently followed by rain before noon, local time.

Cirrus or cirro-stratus clouds moving from the west to northwest in spring, from southwest in summer and autumn, and from west to southwest in winter, are sometimes observed from forty-eight to seventy-two hours before precipitation, but frequently no precipitation occurs after the appearance of these clouds.

Frost is liable to damage fruit during the first half of May and early in November.

The period of observation at this station is too short to admit of accurate deductions; the above statements cover, however, the usual conditions that precede precipitation.

LEXINGTON, KY.

Precipitation is generally preceded eighteen to twenty-four hours by southeast to northeast winds and falling barometer. The severe storms of winter are preceded by east to northeast winds, and preceding summer precipitation the wind is usually from south to east. In spring and summer the barometer generally falls to 29.90 or below, and in autumn and winter to 30 or below before precipitation begins. In spring and summer, during the season of thunderstorms, the barometer is unsteady preceding rain, a condition that is not observed during the colder months.

There is generally a decrease in relative humidity in advance of precipitation. Except as an indication of more rain, during an intermission in a rainstorm, high humidity is not usually a precursor of rain, unless the rain is about to begin. As a rule the humidity can not be depended upon as an indicator of rain.

Cirrus, cirro-stratus, and alto-stratus clouds are almost invariably forerunners of rain in all seasons. These clouds appear about twenty-four hours in advance of precipitation and come from the southwest, except in winter, when they are more often seen coming from the west.

During periods of abnormally high temperature the wind is from the south in spring and winter and from the southwest in summer and autumn. The cold winds of all seasons are from the northwest.

Spring frosts are likely to damage fruit, vegetables, and other crops. In autumn crops are generally matured before the frost season. The general conditions that precede heavy frost are: rising barometer, falling temperature, low humidity, west to northwest winds diminishing in force, and clear or clearing weather.

LITTLE ROCK, ARK.

During the colder months precipitation is preceded twelve to twenty-four hours by south to southeast winds and falling barometer, and precipitation begins when the barometer is near the turn from falling to rising. In connection with storms that come from the southwest, precipitation is preceded by northeast winds and precipitation begins soon after the barometer begins to fall. During the warmer months thunderstorms are preceded six to twelve hours by southerly winds and falling barometer, and the wind shifts to westerly with rising barometer attending the beginning of rain. In all seasons the barometer generally falls to 29.90 or below before precipitation begins.

It has been observed that the moisture of the atmosphere increases twenty-four to forty-eight hours before precipitation in spring and winter and twelve to twenty-four hours before precipitation in summer and autumn, and that the more rapid the increase in moisture the greater the probability of precipitation.

Cirrus and cirro-stratus clouds moving from southwest in spring and summer and from southwest to west in autumn and winter are often observed twenty-four to thirty-six hours before precipitation.

During periods of abnormally high temperature the wind is from the southeast to southwest. During periods of unusually cool or cold weather the wind is from north to northwest, except in summer, when it comes from the east quadrant.

Frost is likely to damage fruit or other crops in March, April, May, September, and October. In spring and autumn frost is preceded by rising barometer, temperature falling to 40° or below at station, light or decreasing northwest winds, low or decreasing humidity, and clear or clearing weather.

LOS ANGELES, CAL.

In spring and winter, including October and November, easterly winds set in twelve and twenty-four hours before precipitation. Normal, followed by falling barometer, generally precedes rain winds. Rain is more likely to begin with the barometer about 29.90 or below in spring and about 29.80 or below in winter.

No increase or decrease in relative humidity is noted preceding rain. Excessive humidity occurs with fog which is rarely an accompaniment of rain, and more than the average humidity follows west to southwest winds from the ocean which are not rain-bearing winds.

Cirro-stratus clouds moving from the west generally forerun storms by periods that vary in length from one to three days, depending upon the movement of the storm-center; when these clouds are not followed by rain the weather usually becomes threatening. Detached masses of clouds, more nearly resembling stratus, are generally observed about midway up the slopes of the Sierra Madre Mountains to the northeast of the station preceding general storms. These clouds are considered a good local sign of rain.

During periods of abnormally high temperature the prevailing winds are from the northeast to northwest in spring, from north to northwest in summer, from east to northwest in autumn, and from northeast to north in winter. The cold winds of all seasons are northerly winds.

Frost is most likely to damage fruit or other crops from December to March. The conditions that generally precede frost are: barometric pressure above the normal but relatively low as compared with pressures to the northward, temperatures at or below normal, low relative humidity, light winds, and a cloudless sky.

LOUISVILLE, KY.

In all seasons precipitation is preceded twelve to thirty-six hours by southeast to northeast winds and falling barometer, and the barometer generally falls to 29.90 or below in spring, summer, and winter, and to 30 or below in autumn before precipitation begins.

There is generally an increase in relative humidity preceding rain. This is most marked in spring and summer, but the period is not well defined. Rapidly increasing moisture after a period of low humidity is a strong indication of approaching rain, but is by no means a sure one.

Cirrus and cirro-stratus clouds indicate rain in this locality at all times of the year, but are far from being a sure sign of approaching rain. The interval between their first appearance and the beginning of precipitation is irregular; they frequently appear for several hours, then disappear, and reappear the next day. The prevailing direction of cirro-stratus clouds is from the west. No special cloud formation is known on which it would be safe to predict rain for this locality twenty-four hours or more in advance, but some cloud formations are of decided assistance when used in connection with a knowledge of the location of approaching storm areas.

During periods of abnormally high temperature the prevailing winds are from southeast to east in spring, from southwest to northwest in summer, and from south to southeast in autumn and winter. During periods of abnormally low temperature the prevailing winds are from west, northwest, or north.

Frost is likely to damage fruit or other crops from March 20 to April 30 and from September 15 to October 15. The general conditions that precede heavy frost are high barometric pressure following an area of low barometer, rapidly falling temperature, decreasing humidity, brisk west to north winds becoming light and nearly calm, and clouds disappearing and leaving a clear sky.

LYNCHBURG, VA.

Precipitation is usually preceded ten to twenty-four hours by easterly winds and falling barometer, and the barometer falls to 30 or below before precipitation begins, except in the case of storms that advance from the southwest, when precipitation begins shortly after the turn in the barometer from rising to falling.

Increasing atmospheric moisture indicates rain at all seasons, especially when accompanied by other favorable conditions, and its value in this respect is greatest during the summer months. The increase is usually noted twelve to eighteen hours before rain begins.

Cirrus and cirro-stratus clouds are usually forerunners of precipitation by twelve to eighteen hours in the warmer and twenty-four to forty-eight hours in the colder months. These clouds generally move from the west.

During periods of abnormally high temperature the prevailing winds are from the south in spring and autumn, from south to southwest in summer, and from southwest in winter. The cold winds of all seasons are from the northwest. High easterly winds come with falling and high westerly winds with rising barometer.

Frost is likely to damage apples from April 8 to 20, and peaches and plums from March 17 to 30. Fruit is most frequently damaged when a temperature of 15° or lower follows a warm spell in January or February. Tobacco is most likely to be damaged from September 15 to October 20. Heavy frost is generally preceded by barometric pressure rising above the normal, falling temperature, humidity about or a little below the normal, light north to northwest winds, and few if any clouds.

MACON, GA.

In spring and summer precipitation is usually preceded about twelve hours by southerly winds and falling barometer, and rain begins near the turn in the barometer from falling to rising. In autumn and winter northeast winds usually precede rain, and rain begins about the time the minimum barometer is reached. Rain begins most frequently, in all seasons, with the barometer between 29.90 and 30. During the colder months rain will sometimes begin with rising barometer and after the wind has shifted to northwest.

The relative humidity is always higher shortly before and after rains, and in some cases there seems to be an increase in relative humidity thirty-six hours before rain begins, but the available data are too limited to be conclusive. While dry air indicates no rain, moist air does not necessarily indicate rain.

Cirrus clouds moving from the southwest merging into cirro-stratus and alto-stratus on the southwest horizon are usually followed by rain in from twelve to thirty-six hours. Detached cirrus, cumulus, and stratus clouds have little significance. In winter high alto-cumulus clouds from the west are some indication of snow if they come in the evening and show a tendency to thicken.

The cold winds of spring and winter are from the northwest, of summer from northwest, northeast, and southeast, and of autumn from northwest to northeast.

Heavy frost is likely to damage cotton during the first two weeks in November. Fruit will be damaged by a spring freeze after the buds have formed, and by a severe freeze in the latter part of February and the beginning of March. Frost is preceded by rising or high barometer, falling or stationary temperature, north to west winds diminishing to almost a calm, moderate humidity, and few if any clouds.

MEMPHIS, TENN.

In spring, autumn, and winter precipitation is preceded by south to southeast winds, and in summer by southwest winds. Preceding storms that advance from the southwest the winds come from the east or northeast. In all seasons, except in winter, precipitation that is preceded by south to southeast winds begins about the time the barometer is on the turn from falling to rising. When the wind is from the east and northeast rain begins with the barometer falling. In winter rain comes with falling, and snow with rising, barometer. Precipitation begins in spring with the barometer about 29.90, or below; in summer and autumn, with the barometer 30, or below; and in winter, with the barometer about 30.10, or below.

An increase in relative humidity is observed twenty-four hours or more before precipitation begins, except that a decrease in humidity is frequently noted at the morning observation on the day preceding rain.

In the spring cirrus clouds moving from the west or southwest and cirro-stratus from the southwest precede rain six to twelve hours. In summer cirrus or cirro-stratus clouds moving from the southwest are followed by rain in from twelve to twenty hours. In autumn and winter cirrus or cirro-stratus clouds from the west or southwest (especially from the southwest) are followed by rain within twenty-four hours, and this cloud movement is a sure sign of rain when the surface wind is from south or southeast.

During periods of abnormally high temperature the prevailing winds are from the southeast in spring, from the southwest in summer, and from south to southwest in autumn and winter. In all seasons the cold winds come from the northwest and incline more toward northerly in the autumn. During winter, early spring, and late autumn periods of unusual cold are usually followed by rain within thirty-six to forty-eight hours. The high winds of all seasons come from west to northwest with rising barometer, except in the case of summer thunderstorms, when they are from southwest to west.

Frost is most likely to damage fruit or other crops in March, April, May, September, and October. The greatest damage to fruit can occur during the latter part of March and the early part of April. Frosts late in October injure the "top crop" in cotton. The general conditions that favor heavy frost are rising barometer for twenty-four hours, wind shifting to fresh northwest, and decreasing, low relative humidity, and clearing or clear sky.

MARQUETTE, MICH.

Storms from the southwest are preceded by east to northeast winds and falling barometer, and in winter precipitation begins shortly after these conditions are developed. Storms from the west and northwest are preceded by southeast shifting to southwest winds and falling barometer, and precipitation begins about the time the barometer is near the turn from falling to rising. During the colder months precipitation comes in the form of snow, with northeast winds and falling barometer, and snow continues after the wind shifts to north and northwest with rising barometer. The upper peninsula of Michigan is probably the most difficult section in the United States for which to forecast precipitation. The usual premonitary signs of weather changes, more particularly as regards rain and snow, fail utterly at times, and precipitation appears to depend upon the relative amount of moisture in the air, and the difference in temperature at points along the south shore of Lake Superior and the temperature of the air that is brought thither from the land in summer and from the lake in winter. In short, the cold necessary for condensation of moisture is a subject for close calculations of wind directions, which in this section are extremely difficult to make.

An increase in relative humidity is generally observed several hours before precipitation, but, at times, when the wind shifts suddenly to points from over the lake the increase is rapid and the chance of subsequent precipitation is again dependent upon temperature conditions.

In spring, summer, and autumn cirrus clouds moving from the west are often observed eight to thirty hours before precipitation. In winter the upper clouds are seldom seen, owing to the prevalence of stratus or nimbus clouds. Alto-stratus and stratus clouds moving from the west or northwest in spring and autumn, from the southwest, west, or northwest in summer, and from the west, northwest, north, and northeast in winter are observed preceding precipitation.

The high winds of spring, summer, and autumn come from the southeast to southwest with falling barometer, and in winter they usually come from the northwest with rising barometer. The warm winds of spring and autumn are from the south, of summer from south to southwest, and in winter abnormally high temperature prevails with calm air or light south to southwest winds. The cold winds of spring come from the southwest and west, of summer from north and northeast, of autumn from the west, and of winter from the southwest, west, and northwest.

Frost is likely to damage crops from June 1 until the early part of September. The conditions under which frost occurs are high barometric pressure, temperature below 40°, low humidity, calm air, and no clouds.

MERIDIAN, MISS.

Easterly winds and falling barometer precede rain six to twenty-four hours in spring. In summer southeast winds and falling barometer precede general rains five to ten hours, and local rains come on the turn of the barometer from falling to rising. In autumn rain is preceded twelve to twenty-four hours by northeast winds and falling barometer. In winter the barometer usually falls five to fifteen hours, with northeast to southeast winds, before precipitation begins, and sometimes light precipitation occurs after the barometer begins to rise. In spring and summer the barometer generally falls to 30 or below, and in autumn and winter to 30.05 or below, before precipitation begins.

Precipitation is usually preceded by an increase in relative humidity in spring and summer, and a decrease followed by an increase in relative humidity in autumn and winter. In summer an increase in the amount of moisture in the air is a good indication of rain; in spring and autumn it is an indication of rain only during cloudy conditions; in winter it is an occasional but not a good indication of rain.

The upper clouds, especially the cirro-cumulus, are forerunners of rain in all seasons. In spring and autumn cirrus or cirro-stratus clouds moving from the southwest appear about twenty hours before rain, and in summer and winter these clouds appear, moving from the west, six to twenty-four hours before precipitation begins. Rain seldom fails to follow well-defined cirro-cumulus clouds at any season of the year.

The warm winds of spring are southerly, of summer westerly and northwesterly and occasionally southwesterly, of autumn southwesterly, and of winter southerly and southwesterly. The cold winds of all seasons are northwesterly, inclining in winter toward northerly.

Frost is likely to damage fruit or other crops from February 15 to May 15 and from September 15 to November 10. Heavy frost occurs more readily in the spring than in the autumn, owing possibly to the temperature of the soil and plants; conditions that will produce a heavy frost in spring will not result in as heavy a frost in autumn.

Frost generally occurs on the second or third night of a cold spell, with light wind, clear weather, humidity low on the preceding day, and moderately high and nearly stationary barometer.

MILWAUKEE, WIS.

Precipitation is usually preceded twelve to twenty-four hours by winds that set in from the east quadrants with falling barometer, and the barometer generally falls to 30 or below before precipitation begins. When storms advance from the west or northwest, the wind sets in from the southeast quadrant, and during the warmer months rain generally begins about the turn of the barometer from falling to rising. When storms advance from the south or southwest, the wind sets in from the northeast quadrant and precipitation usually begins while the barometer is falling. During the colder months snow often begins closely following the shift of wind to the northeast quadrant and with high but falling barometer. The strength of a storm depends on the rate and amount of the fall in the barometer.

The relative humidity usually increases before precipitation, but owing to the fact that the "rain winds" blow from over the lake, it is not possible to distinguish between local and general humidity conditions as indicators of precipitation. The humidity must, in each instance, be considered in connection with other indications.

Cirrus and cirro-stratus clouds move from the southwest in spring and winter and from the west in summer and autumn. The appearance of these clouds is often followed within twelve to twenty-four hours by precipitation.

The highest wind velocities of summer usually come with wind shifting from southerly to westerly and on the turn in the barometer from falling to rising. Occasionally, however, high velocities occur in summer with easterly winds and falling barometer. The highest velocities of the colder months generally come with southeast to northeast winds and falling barometer, which attend the approach of storms from the lower Missouri Valley or the Southwest. High velocities also occur during the colder months from the west and northwest with rising barometer.

During periods of abnormally high temperature the wind comes from south to southwest in spring and autumn, from points between south and west in summer, and from northeast to southeast in winter. The cold winds of early spring are from west to north points, of late spring and summer from points between southeast and northeast, and of late autumn and winter from west, northwest, and north.

Fruit is likely to be damaged by frost during the blooming period, which extends from April 15 to June 1. The cranberry crop is subject to damage by frost in the autumn.

The general conditions that usually precede the occurrence of heavy frost are: Barometer rising above the normal, temperature falling to 40° or below, light westerly winds, and a clear sky.

MINNEAPOLIS, MINN.

In spring, autumn, and winter precipitation is preceded by southeast to northeast winds and falling barometer, and precipitation usually begins when the barometer has fallen to 29.90 or below. In summer rain generally begins with the shift of wind to westerly and near the turn of the barometer from falling to rising. During the colder months light precipitation frequently continues after the barometer begins to rise and the wind has shifted to points between west and northwest.

No note has been made at this station of either the humidity of the air or clouds, nor of their observed relation to precipitation. (See St. Paul report.)

Very little injury is caused by frost before May 15. Frost as late as June 5 affects barley, oats, corn, vegetables, and fruit to some extent. Frost usually occurs under the crest of a high-pressure area, with low temperature, low humidity, clear weather, and nearly calm air, following a northwest wind.

MOBILE, ALA.

In spring and winter rain is preceded twenty-four to forty-eight hours by southerly winds and falling barometer, and the barometer falls to 30 or below before rain begins. In summer and autumn rain is preceded twenty-four to thirty-six hours by south to southeast winds, and rain usually begins after the turn in the barometer from falling to rising.

In spring and winter high winds generally come from the northwest with rising barometer; in summer the high winds are usually easterly and occur in connection with thunderstorms; the high winds of autumn are more often from the southeast with falling barometer.

An increase in relative humidity is noted two to three days before rain, except in the case of summer thunderstorms, when the increase is shown about eight hours before rain begins.

Cirrus or cirro-stratus clouds, moving from the west in spring and winter, from the southwest in autumn, and with no apparent direction of movement in summer, often precede precipitation twenty-four to forty-eight hours.

The warm winds of spring and winter are from southerly directions, and in summer and early autumn periods of unusually high temperature are attended by northerly winds. The cold winds of winter come from north to northwest.

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Frost is likely to damage fruit or other crops from September to April, inclusive. As the climate of this district permits the production of crops of some description, in all seasons, the occurrence of frost will, at any time, cause damage. The conditions favorable for frost are high barometric pressure, temperature as observed at station 40° or below, light wind, and clear weather.

MONTGOMERY, ALA.

In spring and summer precipitation is usually preceded by southeast winds about thirty hours, and in autumn and winter by easterly winds from eighteen to twenty-four hours. In all seasons the barometer generally falls to 30 or below before precipitation begins, although in summer and autumn precipitation may begin with rises in the barometer which come from high barometer areas backing in or spreading from the east. This is most noticeable in winter. A barometric depression over southern Texas or Louisiana is an almost positive indication of rain in this section within twelve to eighteen hours. If the low area moves eastward along the Gulf coast the rains are light to moderate, but continue longer; if the low area moves northeastward the rainfall is heavy, but is quickly followed by clearing weather.

The relative humidity usually increases about twenty-four hours preceding rain, particularly in spring and winter, and the more marked the increase the greater is the likelihood of rain.

Cirrus clouds usually appear in patches in the western sky ten to twenty-four hours before rain, and settle to cirro-stratus as rain approaches. In autumn, winter, and spring a bank of cirro-stratus clouds in the southwestern sky is almost sure to be followed by rain within twelve hours. In summer low cumulus clouds moving from the south in the morning are quite often followed by showers in the afternoon.

During periods of abnormally high temperature the winds are from the south in spring, from northwest to north in summer, and from southeast to southwest in autumn and winter. During periods of unusually cold weather the winds are from the northeast to north in spring, from northeast to east in summer, from northwest to northeast in autumn, and from west to north in winter.

During March, April, and May fruit and early vegetables are subject to damage by frost. Cotton is likely to be damaged by frost during the latter part of April and in May and also in September and October. Sugar cane is in a condition to be damaged by frost in September and October. The general conditions that precede heavy frost are increasing barometric pressure, rather low humidity, light winds, mostly from west to north, and an absence of lower clouds.

MOORHEAD, MINN.

In all seasons precipitation is preceded about twelve hours by falling barometer and southeast winds, and the barometer falls to 30 or below in spring and winter, and to 29.90 or below in summer and autumn, before precipitation begins.

There is usually an increase in relative humidity several hours before precipitation begins.

Cirrus or cirro-stratus clouds are usually observed moving from the west six to twelve hours before precipitation begins.

The warm winds of all seasons are from the southeast and the cold winds from the northwest.

From August 15 to September 30 frost will damage wheat, flax, and other grain that is not ripe.

Damaging frost is likely to occur when pressure above 30, temperature about freezing, relative humidity 70 to 90 per cent, southeast winds, and partly cloudy or clear weather are indicated.

NANTUCKET, MASS.

Precipitation is generally preceded by falling barometer and southerly winds, and begins twelve to twenty-four hours after the barometer begins to fall, and after it reaches 29.90 or below in spring, summer, and autumn, and 30 or below in winter. In the case of storms that advance from the southern quadrants, however, precipitation begins soon after the wind shifts to east or northeast, and closely following the turn in the barometer from rising to falling.

There is usually an increase in relative humidity twelve to twenty-four hours before precipitation. The prevalence of fog in spring, summer, and autumn also has the effect of causing high humidity.

In the spring cirrus or cirro-stratus clouds moving from the north and northwest often precede precipitation twelve to twenty-four hours; in summer and autumn alto-stratus clouds moving from southwest, west, or northwest precede precipitation twelve to twenty-four hours; in winter upper clouds moving from the northwest quickly change to stratus preceding precipitation.

High winds generally come from the southerly with falling barometer, from the northwest with rising barometer, and from the northeast with either rising or falling barometer.

The warm winds of all seasons are from the southwest, and the cold winds from northeast in spring, summer and autumn, and from northwest in winter.

Damage may be caused by frost from May 1 to July 1, and during September. Frost will occur with high barometer, temperature about 40°, relative humidity 54 to 83 per cent, fresh northeast winds during the early evening that flatten out during the night with a cloudless sky.

NASHVILLE, TENN.

Precipitation is usually preceded twelve to twenty-four hours by southerly winds and falling barometer; in cases where storms advance from the Gulf of Mexico or the Rio Grande valley precipitation is preceded by easterly winds. During the colder months the barometer falls to 30 or below before precipitation begins; in summer showers come about the time of the turn in the barometer from falling to rising.

There is generally an increase in relative humidity twelve to twenty-four hours before precipitation, except in connection with summer showers when the increase in air moisture is at times not appreciable until after rain begins.

Beyond the fact that cirrus and cirro-stratus clouds move from the west no notes have been made at this station regarding the relation between clouds and precipitation.

Periods of abnormally high temperature are associated with south to southeast winds, and periods of abnormally low temperature with north to northwest winds, except in summer, when the cooler winds are from east to northeast.

Frost is likely to damage fruit or other crops from April 1 to May 1, and from about the middle to the last of December. Heavy frost is usually preceded by high barometric pressure, unseasonably low temperature, moderate humidity, light winds, and clear weather.

NEAH BAY, WASH.

In all seasons precipitation is preceded for a short period by southerly winds. During the colder months steady rain sets in with falling barometer, and showers occur with rising barometer. In summer and until late in the autumn precipitation occurs just after the turn in the barometer from falling to rising. Rain begins with the barometer at various heights, but more often after it has fallen to 29.90 inches or below.

Owing to the moisture of the climate in this section no definite increase or decrease of atmospheric moisture can be determined for any considerable period preceding precipitation.

Cirro-cumulus clouds are good indicators of rain, and they appear moving from the west a few hours before precipitation in winter and about twelve hours before in summer.

High winds occur from the southwest to west with rising barometer.

The warm winds of spring and winter are from the south, of spring from the east, and of autumn from the east and south. The cold winds of spring are from west and northwest, of summer from west and southwest, of autumn and winter from northwest and northeast.

No fruit or other crops are raised in the vicinity of Neah Bay.

NEW HAVEN, CONN.

Precipitation is usually preceded about twelve hours by east to southeast winds and falling barometer, except in summer, when showers occur with the shift of wind from southerly to southwest, and on the turn of the barometer from falling to rising. In the case of storms that advance from the south or southwest east to northeast winds precede precipitation and rain or snow begins shortly after the wind shifts to easterly quarters and the barometer begins to fall. Except in the case of storms that come from the south or southwest precipitation generally begins when the barometer has fallen to 29.90 or below in spring, summer, and autumn, and to 30 or below in winter.

On account of the humid condition of the atmosphere at this station, and the prevalence of light fogs, no relation has been detected between the relative humidity and the approach of rain. The winds which precede precipitation, coming from southerly and easterly, are, however, the moist winds, and although an increase of humidity precedes rain, it may not in itself indicate approaching rain.

In spring, summer, and autumn cirro-stratus clouds coming from the west or southwest often precede rain about thirty-six hours. In winter the relation is not so definite and the interval between the appearance of clouds of this type is shorter. During the colder months cirro-stratus clouds more often come from the southwest, and during the warmer months from the west.

The high winds of spring, summer, and autumn are from southeast and northeast with falling barometer, and of winter from southeast or northeast with falling and from northwest with rising barometer.

During periods of abnormally high temperature the wind is from the south in spring, and from southwest in summer, autumn, and winter. The cold winds of spring, autumn, and winter come from northwest to north, and of summer from the southeast.

Frost is likely to damage fruit or other crops from April 15 to June 1, and from September 1 to October 15. Heavy frost is generally preceded by rising barometer, falling temperature, high relative humidity, light northwesterly winds, and few if any clouds.

NEW ORLEANS, LA.

In spring, autumn, and winter southeast or northeast winds set in about twelve hours before precipitation, and in summer southeast winds precede rain about four hours. As a rule the barometer falls when winds from these directions prevail, but, at times, it rises when northeast winds that precede rain occur in the winter. In all seasons the barometer generally falls to 30 or below before precipitation begins.

In all seasons of the year a steady increase in relative humidity for twenty-four hours is, as a rule, followed by rain.

In spring there are no clouds that specially indicate rain. In summer cirrus or cirro-stratus clouds moving from the southwest are nearly always followed by rain in about thirty-six hours. In autumn cirrus or cirro-stratus clouds moving from points between southwest and north are nearly always followed by rain within thirty-six hours. In winter cirrus or cirro-stratus clouds moving from the west precede precipitation for the period named.

High winds occur with falling barometer and south to east winds, and with rising barometer and northeast to northwest winds.

During periods of abnormally high temperature the wind is from south and southeast in spring, from southeast, south, and southwest in summer, from south, southeast, or east in autumn and winter. During periods of abnormally low temperature the wind is from northwest, north, or northeast.

Frost is likely to damage fruit or other crops from October 15 to April 15. Sugar cane is most likely to suffer damage from frost and cold from November 1 to January 15. The general conditions which precede frost are rising barometer, temperature 36° to 40°, humidity low, wind light from northwest to northeast, and few clouds or clear weather

NEW YORK, N. Y.

In spring, autumn, and winter precipitation is preceded twelve to twenty-four hours by south to southeast winds, and in summer twenty-four to forty-eight hours by southerly winds. In spring and autumn the barometer usually falls to 29.90 or below and in winter to 30 or below before precipitation begins. In summer showers generally begin about the turn of the barometer from falling to rising. In the case of storms that come from the south or southwest, however, precipitation is preceded by east to northeast winds, and rain or snow begins closely following the shift of wind to these quarters and the turn in the barometer from rising to falling.

As a rule there is an increase in relative humidity twelve to twenty-four hours before precipitation, and in spring, autumn, and winter rain or snow may be expected when the atmosphere is becoming highly charged with moisture.

Generally speaking, the formation of cirrus and cirro-stratus clouds indicates the coming of rain or snow. No definite interval has been observed between the appearance of these clouds and the beginning of precipitation, but it probably varies from eighteen to thirty-six hours. In the spring and winter cirrus and cirro-stratus clouds come from the west, in summer from the southwest, and in autumn from the west and southwest. Precipitation is indicated in spring by the formation of low clouds, without a very pronounced movement, but usually from easterly quadrants, in summer by the rapid formation of thunder clouds, with shifting and increasing winds, in autumn by low cloud formations moving from easterly quadrants, and in winter by high cloud formation, followed by heavy low clouds and easterly winds.

In all seasons the highest winds generally come from the northwest, with rising barometer.

During periods of abnormally high temperature the wind is from the south in spring and winter, and from the southwest in summer and autumn. During periods of abnormally low temperature the wind is from the northwest in spring, autumn, and winter, and from northwest, north, or northeast in summer.

Frost is likely to damage fruit or other crops in this section from April 1 to May 20. Heavy frost is preceded by high and nearly stationary barometer, temperature below 44°, relative humidity about normal, gentle, or light winds, and an absence of clouds, or, when existing, cirrus clouds.

NORFOLK, VA.

Precipitation is preceded by southerly and easterly winds. Southerly winds precede precipitation, with falling barometer, twelve to twenty-four hours. Precipitation closely follows the shift of wind to east and northeast during the colder months, and precipitation begins during those months, and with east to northeast winds, about the time of the turn of the barometer from rising to falling. During the summer months rain does not necessarily attend a shift of wind to easterly quadrants except in cases where storms are advancing from the south or southwest. In all seasons the barometer usually falls to 30 or below before precipitation begins, except in the case of storms from the south or southwest, when, as before stated, precipitation closely follows the shift of wind to east or northeast, irrespective of the height of the barometer.

During the colder months an increase in relative humidity is a good indication of precipitation, and the increase precedes the beginning of precipitation but a few hours.

Upper clouds moving from the west often precede precipitation twelve to thirty-six hours. In spring cirrus clouds are more often observed; in summer cumulus appear five to ten hours before rain, while in autumn and winter cirro-stratus clouds precede rain twenty-four to thirty-six hours.

The high winds of this station come from southerly and easterly with falling, and from southwest, west, and northwest, with rising barometer.

The warm winds of spring and autumn are from south and southwest; of summer from southwest, west, and northwest, and of winter from the south. The cold winds of spring are from northwest, north, northeast, and east; of summer from north, northeast, and east; of autumn from northwest and north, and of winter from west, northwest, and north.

Frost is likely to damage fruit or other crops after April 1 and before October 15. Heavy frost is preceded by normal or high barometric pressure, temperature below 40°, relative humidity 70 to 85 per cent, wind light from northwest or north, and clearing or clear weather.

NORTH PLATTE, NEBR.

In spring and winter precipitation is preceded about twelve hours by northeast winds and falling barometer and begins about the time the barometer is on the turn from falling to rising. In autumn easterly winds precede precipitation about twelve hours, and in summer rain usually begins with northwest winds and on the turn of the barometer from falling to rising. A rapid fall in the barometer is more often followed by rain or snow than a slow fall. In spring and summer the barometer generally falls to 29.90 or below and in autumn and winter to 30 or below before precipitation begins.

While an increase in relative humidity frequently indicates precipitation, especially during the colder months, it can not be relied upon to any great extent. This increase is shown in spring, autumn, and winter seven to twelve hours before, and in summer about one hour before, precipitation.

In spring, autumn, and winter cirro-stratus clouds moving from the west sometimes appear twenty-four hours in advance of precipitation, and in summer strato-cumulus at times appear about twelve hours before rain begins. The cloud indications of precipitation are, however, slight for any considerable period before the beginning of rain or snow.

High winds come from south to southeast with falling and from northwest with rising barometer.

During periods of abnormally high temperature the wind is from the south in summer and autumn and from the southwest in spring and winter. During periods of abnormally low temperature the wind is from the north in spring and summer, from the west in autumn, and from the northwest in winter.

Frost is likely to damage vegetation during the spring and autumn months. Heavy frost is usually preceded by high baronieteric pressure, temperature near the freezing point, high relative humidity, light westerly winds, and either clear weather or a few cumulus clouds.

OKLAHOMA, OKLA.

Precipitation is preceded twelve to forty-eight hours by south to southeast winds and falling barometer, and begins about the time the barometer falls to 29.90 or below and is near the turn from falling to rising. In winter precipitation often begins when the barometer has fallen to about 30 and after it has begun to rise and the wind has shifted from southerly to northerly.

No definite relation has been observed between atmospheric moisture and precipitation. At times the relative humidity decreases for several days in advance of rain and then increases immediately before precipitation begins.

Cirrus and cirro-stratus clouds are rarely observed, but at times these clouds are noted moving from the northwest one to two days in advance of precipitation.

High southerly winds occur with falling, and high northerly winds with rising barometer.

During periods of abnormally high temperature the winds are from the south. The cold winds of spring, autumn, and winter are from the north, and of summer from the southeast.

Frost is likely to damage crops in March, April, May, September, and the first half of October.

Frost generally occurs with rising or high and stationary barometer, temperature falling to 40° or below, average relative humidity, clear weather, or but few clouds, and light northerly winds.

OMAHA, NEBR.

Precipitation is usually preceded twelve to thirty-six hours by southeast winds and falling barometer, and the barometer falls to 29.90 or below in the warmer months and to 30 or below in the colder months before precipitation begins. In summer and during the month of September rain generally begins after the turn in the barometer from falling to rising.

While some definite relation between precipitation and relative humidity may exist, this relation is not shown by the tabulation of 8 a. m. and 8 p. m. observations. It appears, however, that there is an increase in humidity before precipitation during the colder months and a decrease during the warmer months.

Cirrus or cirro-stratus clouds, moving from the west in spring and winter and from the southwest in summer and autumn, often appear thirty to forty hours before precipitation.

The warm winds of spring, summer, and autumn are from southeast to southwest, and of winter from south to southwest. The cold winds of all seasons are from northwest to north.

Frost is likely to damage fruit or other crops from April 1 to May 15, and from August 20 to October 1.

Damaging frost occurs about the time of the maximum of waves of high barometric pressure, with temperature a little below 40°, decreasing relative humidity, few if any clouds, and light winds from westerly or northerly.

OSWEGO, N. Y.

South to southeast winds generally precede precipitation about twenty-four hours, and the barometer falls to 29.90 or below in spring and summer, and to 30 or below in autumn and winter before precipitation begins. In the case of storms that advance from the southwest, however, the wind shifts to northeast and precipitation begins, closely following this shift of wind and shortly after the barometer begins to fall.

During all seasons of the year there is a decrease of relative humidity twelve to twenty-four hours before precipitation, followed by an increase just preceding the beginning of precipitation. Unusual dryness of the atmosphere has been considered a good indication of rain within the next twenty-four hours.

Cirrus and cirro-stratus clouds, moving from the west, are generally followed by precipitation within twenty-four to forty-eight hours, more especially during the colder months.

High winds occur from the south and southeast with falling, and from the west and northwest with rising barometer.

South winds attend periods of abnormally high temperature. The cold winds of spring and winter come from the northwest, and of summer and early autumn from the southeast.

The critical period of damage by frost in the spring for strawberries and other fruits is from May 15 to about June 10. In the autumn frost will cause damage to tomatoes, grapes, corn, and late potatoes from September 15 to about October 1. In a belt about 4 miles wide, extending along the lake, no damage has been caused by frost in several years; and cold northwest to northeast winds occurring in blossom time are much more feared than frost.

In spring and autumn frost is likely to occur with rising barometer, temperature falling to or below 40°, increasing relative humidity, light southwest to west winds, and few if any clouds.

PALESTINE, TEX.

In spring and summer rain is preceded twelve to forty-eight hours by southerly winds and falling barometer, and in autumn and winter precipitation is preceded to twelve twenty-four hours by southeast to northeast winds and falling barometer. In spring, summer, and early autumn rain usually begins when the barometer has fallen to 29.90, or below, and is on the turn from falling to rising. In late autumn and winter precipitation generally begins when the barometer has fallen to 30 or below and after the turn in the barometer from falling to rising.

A sudden rise of a tenth of an inch in the barometer is more likely to precede a shower than is a sudden fall in the barometer. The barometer is often stationary after falling, just preceding, and during heavy rain. A falling barometer at night, and a rising barometer from a low, precedes rain. Clearing weather occurs when the barometer is well on the turn from a low reading, especially if the wind shifts to northwest.

There is generally an increase in the relative humidity of the air during all seasons twelve to twenty-four hours in advance of precipitation. The increase is, however, most marked immediately before rain begins. It often happens that low humidity is followed by rain within twelve to twenty-four hours. The moisture of the air, in the absence of decreasing temperature, does not operate to any great extent as a sign of approaching rain.

Cirrus and cirro-stratus clouds move from the west. The records show that it is rather the exception for cirrus or cirro-stratus clouds to have any prognostic value as to the time rain is likely to follow. It has been noted, however, that when rain follows the first appearance of cirrus or cirro-stratus clouds it occurs within twenty-four to thirty-six hours. This applies to all seasons of the year. Alto-stratus clouds moving from the west are an infallible sign of rain; stratus on the eastern horizon in the early morning presage rain; lower clouds moving from south or southeast, with northerly winds, bring rain. In summer dense cumulus in the northwest usually presage rain.

High south to southeast winds occur with falling and high west to northwest winds with rising barometer.

During periods of abnormally high temperature the winds are from the south. In spring and winter cold winds come from the northwest and in summer and autumn from the northeast.

Serious damage would result from heavy frost occurring between March 15 and December 1. April and October frosts are much dreaded.

In all seasons the barometer and temperature are above the normal twenty-four to thirty-six hours preceding frost, and frost usually occurs on the second day of falling temperature, with high humidity forty-eight hours preceding and a slight decrease in humidity twenty-four hours preceding its occurrence. Fresh north to northwest winds in spring, fresh north in autumn, and fresh northeast in spring and winter usually precede frost, with as a rule clear skies.

PARKERSBURG, W. VA.

South to east winds and falling barometer usually precede precipitation twelve to twenty-four hours, and the barometer generally falls to 29.90, or below in spring and winter, and to 30 or below in summer and autumn before precipitation begins.

A decrease, followed by an increase, in relative humidity usually precedes precipitation.

Cirrus and cirro-stratus clouds from the west presage rain or snow within twelve to twenty-four hours.

The warm winds of all seasons are from the south, and the cold winds from west, northwest, and north.

Frost is likely to damage fruit or other crops from April 15 to May 30, and from September 30 to October 5.

The conditions that are favorable to the occurrence of frost are an area of high pressure overspreading the Ohio Valley, decreasing temperature and humidity, westerly winds, and clear weather or alto-cumulus clouds.

PENSACOLA, FLA.

Precipitation is preceded by southeast to northeast winds and falling barometer, and the barometer generally falls to 30 or below before precipitation begins. For rainstorms the barometer falls slowly for two or three days and then more rapidly, and rain begins several hours before the lowest point is reached and ends after the barometer has begun to rise. In summer there are showers with slowly falling barometer until shortly before the lowest barometer is reached, when there is a heavier fall of rain. In fall and winter rain often begins shortly after the barometer begins to fall.

Except in summer there is an increase in relative humidity noted at the morning observation of days on which rain falls. The humidity at that hour does not in itself indicate rain, but when coupled with temperature above the normal and rain winds it does. A warm, moist atmosphere is often present before fog.

Cirrus and cirro-stratus clouds have been generally observed moving from the northwest, and at times have preceded rainstorms about twenty-four hours. Cirro-stratus merging into alto-stratus, strato-cumulus, and stratus presage rain. Cirrus and cirro-stratus have been observed without rain, but when these clouds merge into clouds of lower formation rain usually follows.

The highest winds of this station generally come from the southwest with falling barometer and near the turn from falling to rising barometer.

During periods of abnormally high temperature the winds are from southeast to southwest in spring and winter, from northwest to northeast in summer, and from north to east in autumn. The cold winds of spring and winter are from the northwest to northeast, of summer from northeast to southeast, and of autumn from north to northeast.

No fruit is raised in this vicinity, and the few vegetables that are grown are subject to damage by frost during all seasons of the year.

The general conditions that precede heavy frost are rising or high barometer, falling or low and stationary temperature, low relative humidity, few if any clouds, and light northwest wind.

PHILADELPHIA, PA.

Precipitation is generally preceded twelve to twenty-four hours by south to east winds and falling barometer, and the barometer usually falls to 30 or below before precipitation begins. In the case of storms that advance from the south and southwest, however, precipitation begins closely following the shift of the wind to east or northeast, and often when the barometer is on the turn from rising to falling; this is more particularly true with regard to south and southwest storms of the colder months.

In spring, autumn, and winter there is an increase in relative humidity to 80 per cent or over six to twelve hours before precipitation begins, and in summer there is an increase to 70 per cent or over one to six hours before rain.

Cirrus and cirro-stratus clouds moving from the west are frequently observed twelve to twenty-four hours before precipitation. First comes the cirrus then cirro-stratus, followed by haze or stratus, and sometimes cirro-cumulus.

High northwest winds occur with rising barometer in spring, autumn, and winter, and high northeast winds with falling barometer. In summer high winds usually come from the south and southwest about the time of the turn in the barometer from falling to rising.

The warmer winds of all seasons come from the southwest. During the warmer months the cool winds come from the northeast, and during the colder months the cold winds come from the northwest.

Frost is likely to damage fruit and other crops from April 10 to May 10, and before October 15.

The conditions that favor the occurrence of heavy frost are high and increasing barometric pressure, temperature 40° and falling, relative humidity normal or below, cumulus clouds followed by clearing, and light northerly or westerly winds.

PHOENIX, ARIZ.

In spring and winter southeast to southwest winds and falling barometer precede precipitation for periods that average about twenty-four hours, and the barometer falls to about 29.90 or below before precipitation begins. From late in the spring until the beginning of winter the prevailing winds are from the easterly, and preceding rain the wind shifts to northerly or northwesterly, with falling barometer.

While there is usually an increase in relative humidity preceding rain, rain sometimes occurs when the surface air shows a decreasing amount of moisture.

Cirrus and cirro-stratus clouds move from the west and are forerunners of rain only to a limited extent.

High winds occur with a falling barometer from the southwest in spring, from east and southeast in summer, from southeast in autumn, and from the west in winter.

The cold winds of spring, autumn, and winter come from the west and northwest.

Frost is likely to do damage in December, when citrus fruits are still on the trees, and in February and March, when citrus trees and almond trees are budding and blooming.

The conditions favorable for frost are low followed by rising barometer, temperature falling to or below 40°, few if any clouds, and southwest or west veering to light northwest or north winds.

PIERRE, S. DAK.

In all seasons precipitation is preceded twelve to twenty-four hours by east to south winds and falling barometer, and precipitation begins after the turn in the barometer from falling to rising. In spring, summer, and autumn the barometer falls to 29.90 or below and in winter to 30 or below before precipitation begins.

At times, and more especially during the colder months, there is an increase in relative humidity twelve to twenty-four hours before precipitation; as a rule, however, the increase is not marked at the hours of regular observation.

Cirrus and cirro-stratus clouds move from the west and northwest in spring and winter, from west and southwest in summer, and from west in the autumn, and the period of their appearance before precipitation varies from six to seventy-two hours. In spring if these clouds merge into alto-stratus rain falls within twelve hours. In summer if they increase in density during the heat of the day they are at times followed by thunderstorms. In autumn the conditions are not well marked. In winter increasing alto-stratus clouds are followed by snow, often in four to six hours, but more frequently in six to twelve hours. Cirro-stratus to alto-stratus moving with moderate speed from a westerly direction, strato-cumulus from the same direction as the surface wind that is blowing brisk from southeast or east and continuing twenty-four to seventy-two hours presage rain. This type is most prominent in spring, summer, and fall. Alto-cumulus that follow alto-stratus are often followed by rain in six to twelve hours, and constitutes the best type for the year round. Alto-stratus in winter moving from the southwest at moderate speed usually presage rain or snow.

During periods of abnormally high temperature the wind blows from southeast and south in spring and summer, and from southeast to southwest in autumn and winter. The cold winds of all seasons are northerly winds.

Frost is likely to cause damage from the middle of April to the first week in June, and from the last of August to the first week in October. In spring heavy frost will occur with high barometric pressure, temperature 42° to 54° and falling, low humidity, northerly winds becoming light and variable, and alto-stratus or strato-cumulus clouds clearing away about sunset. In the late fall and winter months the humidity is generally higher before frost, and frost often fails to occur when other conditions are favorable for its occurrence, owing to low humidity, especially in late fall, winter, and early spring.

PITTSBURG, PA.

Precipitation is usually preceded by southeast to northeast winds and falling barometer for periods of ten to twenty-four hours, and the barometer generally falls to 29.95 or below in spring and autumn and to 29.90 or below in summer and winter before precipitation begins. In the case of storms that advance from the south and southwest, however, precipitation often begins closely following the shift of wind to the northeast and the turn in the barometer from rising to falling.

A low percentage of relative humidity generally indicates fair weather for the next twenty-four hours. In spring and summer rapidly increasing relative humidity indicates approaching thunderstorms. In autumn and winter the relative humidity is abnormally low twenty-four hours before precipitation and then begins to increase. Whem abnormally low at 8 a. m. a shower generally occurs before night.

Nothing satisfactory can be given regarding cloud observations on account of the smoky conditions that prevail.

The high winds of all seasons usually come from the southwest with falling and from the west with rising barometer.

During periods of abnormally high temperature the wind comes from the south in spring and winter, from the south and southwest in summer, and from the southeast in autumn. The cold winds of all seasons come from northwest to north.

Frost is likely to damage fruit or other crops in May and September.

The conditions that favor the occurrence of frost are rising and high barometer, temperature falling to 40° or below, a decrease of about 10 per cent in relative humidity eight to twelve hours preceding frost, light winds and clear weather.

POCATELLO, IDAHO.

In spring and autumn precipitation is preceded about twelve hours by south to west wind and falling barometer, in summer about six hours by south winds, and in winter snow is preceded twelve to twenty-four hours by southwest winds. In all seasons the barometer falls to about 29.80 or below and begins to rise before precipitation begins.

In spring and autumn there is a slight increase in relative humidity six to twelve hours before precipitation, and in winter an increase occurs twelve to twenty-four hours before precipitation. In summer there is an apparent decrease in relative humidity about twelve hours before rain.

Precipitation is generally preceded twelve to twenty-four hours by the appearance of upper clouds. Alto-stratus appears, however, to have been the kind of clouds most frequently noted at this station in connection with precipitation.

The high winds of this station come with rising barometer and when they shift from southerly to westerly.

The warm winds of spring and winter come from the south, of summer from south to southeast, and of autumn from the southeast. The cold winds of spring and winter come from the northwest, of summer from the west, and of autumn from the north.

Frost is most likely to cause damage to vegetation during the first ten days of April.

The conditions that favor the occurrence of frost are, high or rising barometer, clear weather, light winds, with low humidity in spring and high humidity in autumn.

PORT CRESCENT, WASH.

Precipitation is preceded three to six hours by falling barometer and southeast winds, and the barometer usually falls to about 29.90 or below before precipitation begins. In summer rain begins about the time of the turn in the barometer from falling to rising.

There is generally an increase in relative humidity to about 96 per cent, a few hours before precipitation begins except in summer, when no decided humidity changes have been noted in connection with approaching rain.

Cirro-stratus and cirrus clouds move from the west, but no relation between these or other clouds and rain has been noted at this station.

The high winds of spring, autumn, and winter come from the southerly with falling barometer, and the high winds of summer from westerly with rising barometer.

The warm winds of spring, autumn, and winter come from the southeast, and of summer from the east. The cold winds of summer come from the west, and of other seasons from the northeast.

No damage results from frost at this station.

PORTLAND, ME.

Precipitation is preceded twelve to twenty-four hours by southeast to northeast winds and falling barometer, and the barometer usually falls to 29.90 or below before precipitation begins. In the case of storms that advance northeastward from the south Atlantic coast precipitation begins closely following the shift of wind to northeast and the turn in the barometer from rising to falling.

There is generally an increase in relative humidity two to six hours before precipitation begins.

Cirrus and cirro-stratus clouds moving from the west frequently precede precipitation twelve to eighteen hours.

The highest winds of all seasons usually come from southeast to northeast with falling barometer.

The warm winds of spring and autumn come from the southwest and west, of summer from the west, and of winter from the south. The cold winds of spring and winter come from the northwest, of summer from east and south, and of autumn from west and northwest.

Frost is likely to damage fruit or other crops in April and October.

The conditions that favor frost are, rising and high barometer, temperature falling below 40°, low relative humidity, light west to northwest winds, and few if any clouds.

PORTLAND, OREG.

In all seasons precipitation is preceded by southeast winds and falling barometer. In spring the rain winds set in about fourteen hours, in summer about twelve hours, and in autumn and winter about twenty hours before precipitation begins. In spring, summer, and autumn the barometer usually falls to 29.95 or below and in winter to 30 or below before precipitation begins. Wind shifting from northwest to northeast and then to southeast is a good indication of rain at any season of the year. Wind shifting to northwest is a sign of clearing weather.

The relative humidity usually increases fifteen to twenty-four hours before precipitation begins. An increase of 25 to 50 per cent in relative humidity is a fair indication of rain in spring, summer, and fall.

Cirrus and cirro-stratus clouds are generally followed by rain in spring, autumn, and winter, but are not a good indication of rain in summer. Cirro-cumulus clouds are an almost sure sign of rain in autumn, spring, and winter, but are only a fair indication in summer. Cirro-stratus and cirrus clouds move from the west in spring, summer, and winter, and from the northwest in autumn, and appear thirty to thirty-six hours before rain begins.

The highest wind velocities occur with southerly winds and falling barometer.

The warm winds of spring, summer, and autumn come from the northwest, and of winter from the south. The cold winds of spring and summer come from southeast, south, and southwest, and of autumn and winter from southeast to northeast.

Frost is most likely to damage fruit during the month of April, when prunes, peaches, cherries, and pears are in bloom.

Frost is generally preceded by a rather high or rising barometer, temperature slightly higher than usual, relative humidity 60 to 70 per cent,-light to brisk northwest to northeast winds, or light winds if from east or southeast and clear weather.

PORT HURON, MICH.

Precipitation is generally preceded twelve to twenty-four hours by winds that shift to points between south and northeast and increase in force with falling barometer, and the barometer usually falls to 29.80 or below before precipitation begins. During the colder months precipitation often begins soon after the wind goes to northeast and the barometer begins to fall, and snow often continues some hours after the wind shifts to west and northwest and the barometer begins to rise.

In all seasons the relative humidity begins to increase about twelve hours before precipitation; at times, however, the relation between relative humidity and rainfall is not marked.

Cirrus and cirro-stratus clouds observed moving from a westerly direction usually precede precipitation twelve to twenty-four hours, and stratus clouds become more dense on the approach of rain, and in the case of severe storms the movement of stratus clouds is rapid.

High south to northeast winds occur with falling, and high southwest to north winds with rising barometer.

The warm winds of all seasons are from south to southwest, and the cold winds from west to north.

Frost is most likely to damage fruit or other crops after May 1 and before November 1.

The conditions that precede heavy frost are rising barometer, temperature falling in the forties or lower on the day previous, relative humidity normal or below, light winds, and clear or clearing skies.

PUEBLO, COLO.

Precipitation is preceded by northeast winds and falling barometer six to thirty-six hours, and begins after the barometer has fallen to about 29.90 or below in spring, 29.85 or below in summer, 29.95 or below in autumn, and to 30.05 or below in winter, and after the turn in the barometer from falling to rising. In summer, however, rain sometimes begins before the turn in the barometer from falling to rising. In summer, preceding rain which practically always occurs with thunderstorms, the barometer falls under the influence of the diurnal change; eliminating this change the barometer has a slight upward tendency before rain. During late autumn, winter, and early spring cloudy and threatening weather begins only after the barometer has fallen considerable, and precipitation occasionally begins before the barometer has reached the lowest point, but usually not until after a few hours after the rise begins. Precipitation of any considerable duration occurs only when the barometer rises slowly, or remains low and nearly stationary.

In spring, autumn, and winter there is sometimes an increase in relative humidity six to twenty hours before precipitation. In summer neither an increase nor a decrease has been noted.

Cirrus and cirro-stratus clouds moving from the west are observed almost daily. In the spring cumulus, strato-cumulus, and stratus moving from northeast, east, or southeast are usually followed by rain in a few hours. In winter alto-stratus clouds moving slowly from a westerly direction precede precipitation more frequently than any other cloud formation.

The high winds of this place come from northerly with rising barometer.

The warm winds of spring, autumn, and winter come from south to west points, and of summer from southerly. The cold winds of spring, summer, and autumn come from northeast to east, and of winter from north to east.

In the spring fruit buds are likely to be injured by frost after April 20, garden truck after May 1, tomatoes and melons after May 5, and corn after May 10. In the fall, before October 1, crops are either harvested or advanced beyond the stage where injury from frost will result. Melons and tomatoes continue to ripen until killed by frost, and some years their season continues until October 15.

The conditions that are favorable for heavy frost are: Rising barometer, temperature falling to below 40°, relative humidity increasing to from 60 to 90 per cent, light winds, and clear or clearing weather. Light precipitation during the day, followed by rising barometer and clearing weather at night presents a most favorable condition for frost formation both in spring and autumn.

RALEIGH, N. C.

Precipitation is preceded twelve to twenty-four hours by winds blowing from points between south and northeast, and at times in the spring from southwest, and falling barometer, and the barometer usually falls to 30, or below, before precipitation begins, except when winds are from the northeast during the colder months, when it often begins with higher barometer. In summer rain generally begins about the turn in the barometer from falling to rising, and in other seasons while the barometer is falling.

There is usually an increase in relative humidity twelve to twenty-four hours before precipitation. In spring the change in relative humidity has, however, a rather remote relation to rain; in summer there is often a decided decrease about six hours before thunderstorms; in autumn the increase is generally preceded by a marked decrease in relative humidity; in winter the increase indicates rain, except when due to fog.

Cirrus and cirro-stratus clouds from the west are distinctly forerunners of rain in the winter months, and appear twelve to twenty-four hours before rain begins. During summer, however, cirrus clouds often appear that are not followed by rain. If, during the warmer months, cumulus clouds appear early in the day they are more likely to be followed by thunderstorms than cumulus that appear in the afternoon, but in the latter case, if thunderstorms appear, they will be more violent.

The warmer winds of all seasons come from the southwest, and the colder winds from northwest and north, and, in winter, also from the northeast.

The high winds of all seasons come from the northwest with rising barometer; in the spring and summer, however, the high winds set in or begin from the southwest with falling barometer, and quickly shift to northwest with rising barometer.

Frost is likely to damage fruit or other crops from March 15 to May 10, and during October.

Heavy frost is usually preceded by high or rising barometer, temperature about 40° at 8 p. m. on the evening preceding frost, light winds, and a clear sky.

RAPID CITY, S. DAK.

Precipitation is usually preceded twelve to twenty-four hours by southeast to northeast winds and falling barometer, and begins after the turn in the barometer from falling to rising. In spring and summer the barometer generally falls to 29.80 or below, in autumn to 29.90 or below, and in winter to 30 or below before precipitation begins. As a rule, the barometer has fallen below the points indicated and has been rising several hours before precipitation begins.

The relative humidity decreases about twenty-four hours before rain in all seasons of the year, and low relative humidity is a good indication of precipitation.

Cirrus and cirro-stratus clouds moving from the west usually precede rain or snow. There are no other special cloud characteristics of rain that appear sufficiently in advance of precipitation to be of value in forecasting.

The warm winds of spring and summer come from the southwest, of autumn from the south, and of winter from the south and southwest.

The cold winds of spring, summer, and autumn come from the northwest, and of winter from the north and northwest.

Frost is likely to cause damage from May 10 to September 20.

Heavy frost is usually preceded by rising barometer, temperature falling to 40° or below, high relative humidity, light winds, and few if any clouds.

RED BLUFF, CAL.

In spring, autumn, and winter precipitation is usually preceded twenty-four to thirty-six hours by southeast winds and falling barometer, and the barometer generally falls to 29.80 or below before precipitation begins. In summer no rain falls. As the movement of the barometer at this station depends upon the progress of areas of high and low barometric pressure eastward from the Pacific Ocean, and as all general rains in California are associated with storms that advance from the ocean the barometer falls preceding rain and rises preceding clearing weather. If the rain is to be of long duration the barometer falls slowly, if severe and of short duration the barometer falls rapidly.

The relative humidity increases twenty-four to thirty-six hours before precipitation to over 50 per cent in spring, to over 40 per cent in autumn, and to over 80 per cent in winter.

In spring and autumn cirrus clouds moving rapidly from the westerly precede rain twenty-four to thirty-six hours. In winter the interval between the appearance of upper clouds moving from a westerly direction and the beginning of rain is shorter, but the indication is not so often fulfilled.

The high winds usually come from the southeast with falling barometer, and also from the north with rising barometer.

Frost is most likely to damage fruit or other crops from the middle of February to the middle of April.

Heavy frost occurs in the spring following the passage of a storm, with rising barometer, falling temperature, falling dew-point, and winds changing from southerly to westerly. These conditions are preceded by hail or sleet along the foothills. In autumn frost occurs rarely, and is usually preceded by a thunderstorm. In winter frost is preceded by rising barometer, low humidity, and clearing weather. Severe winter frosts are due to an outflow of air from a cold wave over the plateau region.

RICHMOND, VA.

Winds generally set in from the east quadrants, with falling barometer, twenty-four to thirty-five hours preceding precipitation, and the barometer usually falls to 30 or below before precipitation begins, except in the case of storms that advance from the south or southwest

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The cold winds of spring, summer, and autumn come from the northwest, and of winter from the north and northwest.

Frost is likely to cause damage from May 10 to September 20.

Heavy frost is usually preceded by rising barometer, temperature 'alling to 40° or below, high relative humidity, light winds, and few f any clouds.

RED BLUFF, CAL.

In spring, autumn, and winter precipitation is usually preceded wenty-four to thirty-six hours by southeast winds and falling barom- ter, and the barometer generally falls to 29.80 or below before pre- ipitation begins. In summer no rain falls. As the movement of the arometer at this station depends upon the progress of areas of high ıd low barometric pressure eastward from the Pacific Ocean, and as ıl general rains in California are associated with storms that advance om the ocean the barometer falls preceding rain and rises preceding earing weather. If the rain is to be of long duration the barometer lls slowly, if severe and of short duration the barometer falls pidly.

The relative humidity increases twenty-four to thirty-six hours fore precipitation to over 50 per cent in spring, to over 40 per cent autumn, and to over 80 per cent in winter.

In spring and autumn cirrus clouds moving rapidly from the westerly ecede rain twenty-four to thirty-six hours. In winter the interval tween the appearance of upper clouds moving from a westerly direc- n and the beginning of rain is shorter, but the indication is not so ten fulfilled.

The high winds usually come from the southeast with falling barom- r, and also from the north with rising barometer.

Frost is most likely to damage fruit or other crops from the middle February to the middle of April.

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[illegible] lling barom- [illegible] ation, and the [illegible] gins. [illegible] during the colder months, when precipitation begins closely following the turn in the barometer from rising to falling. In summer showers occur on the turn of the barometer from falling to rising.

There is usually an increase in relative humidity for a period of twelve to twenty-four hours before precipitation in all seasons of the year, the period of increase being longer during the colder months.

Cirrus or cirro-stratus clouds moving from a westerly direction often appear twenty-four hours before precipitation. A fine veil of cirrus, nearly approaching the cirro-stratus, drawn out in parallel threads or wisps like the teeth of a comb, presage precipitation. This formation is rare and has been observed only in spring, late autumn, and winter months.

During periods of abnormally high temperature the wind is generally from the southwest, and the cold winds of all seasons usually come from the north.

Frost is likely to damage fruit or other crops after April 1 and before October 31.

Heavy frost occurs with barometer rising or above normal, temperature 40° or below, relative humidity above 75 per cent, few if any clouds, and light westerly or northerly winds.

ROCHESTER, N. Y.

Precipitation is usually preceded twelve to twenty-four hours by southeast to southwest winds and falling barometer, and the barometer generally falls to about 29.90 or below in spring, 29.85 or below in summer, 29.95 or below in autumn, and 30 or below in winter, before precipitation begins. In the case of storms that come from the south or southwest, however, precipitation often sets in closely following the shift of wind to the northeast and the turn in the barometer from rising to falling.

The relative humidity generally decreases before precipitation in March for a period of about thirty-six hours, and in April and May for an average period of about three days. In summer and autumn the decrease is noted for about two days preceding rain, and in winter the period is about thirty-six hours. In the spring the humidity will often decrease and remain low for several days without rain, and again rain will continue several days with low humidity. Rain begins with relative humidity 50 per cent and above, and dry weather often accompanies high humidity. Decreasing relative humidity generally attends decreasing pressure and increasing relative humidity increasing atmospheric pressure.

Cirrus and cirro-stratus clouds move from the west. In winter and early spring the sky is almost constantly overcast and cirrus and cirro-stratus clouds can seldom be seen. During periods of clear weather, however, their appearance precedes rain for an average period of about thirty hours. In summer and autumn cirrus and cirro-stratus clouds appearing during a period of clear weather presage rain within twenty-four to thirty hours.

The high winds of this station usually come from southwest to northwest, with rising barometer.

The warm winds of all seasons come from the southwest, and the cold winds from southwest, west, and northwest.

Frost is likely to damage fruit or other crops in late spring and early autumn.

Frost is generally preceded by rising barometer, temperature falling to 40° or below, relative humidity moderately low, light winds, generally from westerly directions, and few if any clouds.

ROSEBURG, OREG.

In spring and summer precipitation is preceded twelve to twenty-four hours by southwest winds and falling barometer, and in winter about twelve hours by southerly winds and falling barometer. In spring and summer precipitation usually begins after the turn in the barometer from falling to rising, and in autumn and winter while the barometer is falling. In spring, summer, and winter the barometer generally falls to 29.90 or below, and in autumn to 29.80 or below before precipitation begins.

In summer there is an increase in relative humidity twenty-four to thirty-six hours before rain; in other seasons the relation between changes in relative humidity and precipitation has not been defined.

In spring and summer cirro-stratus clouds moving from the southwest often precede precipitation twenty-four to forty-eight hours. In autumn and winter cirro-cumulus clouds from the southwest or south precede precipitation twelve to twenty-four hours.

In spring, autumn, and winter high winds come from southerly, with falling barometer. In summer high winds seldom occur, but when they do they come from southeast, east, or northeast.

The warm winds of spring and summer are northerly, and of autumn and winter southerly. The cold winds of spring, summer, and winter come from the northwest and of autumn from the northeast.

Frost is likely to damage fruit or other crops during the late spring.

The conditions favorable for heavy frost are: Barometer high or rising, temperature falling to 40° or below, increasing relative humidity, clearing or clear weather, and light winds.

SACRAMENTO, CAL.

In spring, autumn, and winter precipitation is preceded by northerly shifting to southeasterly winds and falling barometer, and begins near the turn in the barometer from falling to rising. In spring and winter the barometer usually falls to 29.80 or below, and in autumn to

29.90 or below before precipitation begins. Rain sometimes continues several days after the barometer begins to rise. Practically no rain falls in summer.

The relation between atmospheric moisture and precipitation has not been determined at this station.

Cirro-stratus clouds move from the southwest in spring and autumn, and from the northwest in winter; but the relation between cloud forms and precipitation has not been noted by the observer.

High winds come from the northwest with rising, and from south west to southeast with falling barometer.

The warm winds of all seasons come from northwest to north, and the cold winds from southerly directions.

Frost will injure vegetables and garden truck in April and sometimes in May, deciduous fruits in March and April, and citrus fruits in November and December.

Heavy frost is usually preceded by high barometer, north to east winds becoming very light, a low percentage of relative humidity, and a clear sky, though sometimes accompanied by fog.

ST. LOUIS, MO.

During the colder months precipitation is preceded twelve to twenty-four hours by winds from points between south and northeast, and falling barometer, and the barometer usually falls to 29.90 or below in early spring and to 30 or below in winter before precipitation begins. During the warmer months rain is preceded for somewhat longer periods than in winter by winds from southwest to southeast and falling barometer, and the barometer falls to about 29.90 or below before rain begins. In the case of summer showers rain begins about the time of the turn in the barometer from falling to rising, and when the wind shifts from southerly to westerly.

As a rule, the relative humidity increases twenty-four to forty-eight hours before precipitation begins, the period being somewhat shorter in the colder than in the warmer months.

Cirrus and cirro-stratus clouds moving from the southwest are often observed preceding precipitation, and they afford a more reliable indication of precipitation in the colder than in the warmer months. In the spring these clouds change rapidly to alto-stratus and alto-cumulus before rain, and in winter alto-cumulus appear in advance of the precipitation-bearing stratus clouds.

High winds usually come from the western quadrants with rising barometer. In spring, however, high winds often come from the northeast.

The warm winds of all seasons come from the south, and the cold winds from west to northwest.

Frost is likely to damage fruit or other crops in April, and from September 1 to the latter part of October.

In spring and autumn heavy frost is generally preceded by rising barometer, temperature falling to 40° or below, relative humidity 75 per cent or less, light northerly winds, and clear weather.

ST. PAUL, MINN.

Precipitation is preceded eight to twenty-four hours by southerly or easterly winds and falling barometer, and the barometer usually falls to 29.90 or below before precipitation begins.

The relative humidity generally increases two to twelve hours before precipitation, relative humidity 60 per cent in summer, 70 per cent in spring and autumn, and 80 per cent in winter is usually followed by precipitation.

Cirro-stratus clouds from the west in spring, summer, and winter, and from the northwest in autumn are usually followed by precipitation in twelve to twenty-four hours. Precipitation is often preceded by clouds that resemble white sheets with dark, irregular edges, which float slowly from directions between southwest and west. They appear to be a development of the alto-stratus toward the strato-cumulus, and are more common to the summer than to the winter months.

The high winds of spring, autumn, and winter come with rising barometer and from southwest shifting to northwest, and of summer from southeast to southwest with falling barometer.

During periods of abnormally high temperature the wind is from points between southeast and south in spring and autumn, from southeast to southwest in summer, and from southerly in winter. The cold winds of all seasons come from northwest to north.

Frost is likely to damage fruit or other crops in May and September.

Heavy frost is preceded by high barometric pressure, temperature 40°, or slightly below, relative humidity 45 to 60 per cent, light west to northwest winds, and few if any clouds.

SAN ANTONIO, TEX.

Precipitation is usually preceded six to twenty-four hours by southeast winds and falling barometer and, as a rule, begins about the time of the turn in the barometer from falling to rising. In summer the period is somewhat longer. In the case of storms whose centers pass to the south of station the winds go to northerly by way of easterly. In spring the barometer usually falls to 29.90 or below, in summer to 29.95 or below, and in autumn and winter to 30 or below before precipitation begins. Irregular and oscillating barometer, and barometer below the normal with northerly winds, indicates rain.

There is invariably an increase in relative humidity before rain, the period of increase varying from six to forty-eight hours in spring and summer, six to thirty-six hours in autumn, and six to twenty-four hours in winter. Excessive moisture is always an indication of rain.

Cirro-stratus clouds moving from the west or southwest precede rain by periods that vary from three to forty-eight hours, the periods being greater in autumn and winter. These clouds merge into clouds of lower formation. In spring columnar cumulus, with cirrus haze at low levels, moving from the southeast, indicate strong wind and heavy rain. In summer and autumn cumulo-nimbus banking in the northeast or northwest indicate showers for a day or two; mammillate cumulus from the southeast indicate thunderstorms; and cloud banks in the west or northwest indicate rain. In winter ribbed cirrus, with watery-looking patches at lower level, and hair-rooted cirro-stratus moving from west or southwest presage rain; so also alto-cumulus from southeast with northerly winds.

The warm winds of spring and winter come from south and southeast, of summer from southeast, southwest, and northwest, and of autumn from northeast. The cold winds of spring and winter come from points between west and north, of summer from the northeast, and of autumn from the north.

Fruit is subject to damage by frost in March and April, and garden truck from October to April, inclusive.

Heavy frost is generally preceded by high barometric pressure, a high percentage of relative humidity, temperature 40° or slightly below, light winds, and few if any clouds.

SALT LAKE CITY, UTAH.

In spring precipitation is generally preceded about two days by south to southwest winds and falling barometer, and the barometer falls to about 29.70 and is on the rise before precipitation begins. In autumn and winter southerly winds and falling barometer precede precipitation about two days, and the barometer falls to a minimum of about 29.80 in autumn and to a minimum somewhat above 30 in winter and is on the rise before precipitation begins. In summer northwest winds and falling barometer precede rain about twenty-four hours, and the barometer falls to about 29.85 and is on the rise before rain begins. In spring, autumn, and winter "rain winds" are produced by an area of low pressure passing in over the Washington coast, or the formation of a low area over the northern or middle plateau region. During summer they result from a low area over the northern Rocky Mountain slope and a high area over the north Pacific districts.

The relative humidity has not been associated with weather changes.

Cirro-stratus clouds move from the northwest in spring, autumn, and winter, and from the southwest in summer. From April to September they precede rain two to three days, and from October to March one to two days. Precipitation is also preceded by cirro-cumulus clouds.

High winds come, with rising barometer, from the north in spring and winter, and from the northwest in summer and autumn.

The warm winds of all seasons come from the southeast, and the cold winds from the northwest.

Frost will damage fruit or other crops from March 20 to June 10.

The conditions that precede heavy frost are a low barometer area moving off toward the southeast or east; a well-marked high area coming in from the northwest; morning temperature between 40° and 50°; relative humidity about 50 per cent; brisk wind, becoming light, and sky clearing of stratus clouds. This applies to all seasons.

SAN DIEGO, CAL.

In spring precipitation is preceded twelve to twenty-four hours by wind blowing from points between southeast and west and falling barometer, and the barometer falls to about 29.90 or below and is on the turn from falling to rising before rain begins. In autumn southeast to southwest winds and falling barometer precede rain twelve to twenty-four hours, and the barometer generally falls to about 29.80 and is on the turn from falling to rising when rain begins. In winter rain is preceded twelve to forty-eight and sometimes seventy-two hours by southeast to southwest winds and falling barometer, and the barometer falls to about 29.80 or below before rain begins. In summer no rain falls. Preceding rain the barometer is subject to rapid fluctuations, rising and falling a few hundredths in the general fall. The height of the barometer is not at all times material. As a rule the heaviest rain begins after the barometer begins to rise. Clearing weather is preceded a few hours by rapidly rising barometer. Often clearing weather and rising barometer are simultaneous. In the spring southeast to south winds with falling barometer or high west winds with stationary barometer indicate rain. "Sonoras" come with falling barometer and a shifting west to northwest wind.

There is usually a decrease in relative humidity for a few hours preceding rain. A drop of 10 to 20 per cent in relative humidity below a normal of 70 per cent generally precedes rain six to twelve hours. Conditions may be ever so threatening—barometer, clouds, wind direction and velocity, etc.—but if the relative humidity is above 70 per cent, precipitation in a form other than mist is improbable.

In spring cirro-stratus clouds from the south precede rain six to twelve hours, in autumn from the west twelve to thirty-six hours, and in winter from points between southeast and southwest twenty-four to forty-eight and sometimes seventy-two hours. Cirro-cumulus clouds nearly always precede rain. These clouds should be well defined, with darkened convexities. A thick sheet of cirro-stratus clouds will sometimes herald a general rain. During the rainy season a very small streamer-like cloud of a dark shade is generally entwined about a threatening cumulus cloud and always precedes rain. The observer has called these clouds "rope stratus," from their appearance, and they apparently indicate a state bordering on complete saturation. These clouds have no independent direction, but depend on the movement of the accompanying cumulus cloud. Other conditions may be very threatening, but if the clouds have a wave-like appearance, with their crests inclined to the south, no rain will fall. These clouds are frequently seen on the western horizon, and clearly indicate the direction of the upper air currents. The direction of these upper projections, whether they point south or north, indicates respectively fair weather or rain.

In spring and winter high winds come from southeast to southwest points with falling barometer, and from east to north points with rising barometer. No high winds occur in the summer and autumn.

The warm winds of the colder months come from points between east and north. No high temperature occurs in summer. The cold winds of spring, autumn, and winter come from east to northeast points. There are no low temperatures in summer.

Citrus fruit may be damaged by frost at any time of the year, but the critical time for oranges is just before picking, which is generally from December 1 to February 1.

The general conditions which precede heavy frost are: Rising barometer, low temperature and humidity, northerly winds, no clouds, or a streamer-like appearance of filmy cirrus.

SANDUSKY, OHIO.

Precipitation is usually preceded twelve to twenty-four hours by south to southeast winds and falling barometer, and the barometer falls to 29.85 or below in spring and winter, and to 29.80 or below in summer and autumn before precipitation begins. In the case of storms that advance from the south or southwest the wind sets in from points between east and northeast, and precipitation often begins closely following the beginning of the fall in the barometer.

In spring and winter there is an increase in relative humidity twelve to twenty-four hours before precipitation, and in summer there is a slight increase, twelve to thirty-six and sometimes forty-eight hours before rain begins.

Cirrus clouds moving from the west or southwest have often been observed one to two days preceding precipitation.

The high winds of this station generally come from west to northwest with rising barometer.

The warm winds of all seasons are from southerly, and the cold winds from westerly and northerly in spring and winter, and from northeast, north, or northwest in summer and autumn.

Frost is likely to damage fruit or other crops in the spring after April 1 and in the fall during October.

Frost is preceded by rising barometer, temperature falling to 40° or below, increasing relative humidity, light westerly winds, and clear or clearing weather.

SAN FRANCISCO, CAL.

In spring and autumn rain is preceded twenty-four to forty-eight hours by southeast winds and falling barometer, and the barometer usually falls to 29.80 or below in spring, and to 29.90 or below in autumn before rain begins. In summer little or no rain falls. In winter southeast to southwest winds and falling barometer precede rain twelve to forty-eight hours, and the barometer usually falls to 29.80 or below before rain begins. With "Sonora" storms rain sometimes begins with the local barometer 30.10 or above. A marked low barometer area moving southward along the coast in winter presages rain; a marked high area, fair weather.

An increase in relative humidity is noted six to twelve hours before rain in spring, a slight increase about six hours before in autumn, and an increase twelve to twenty-four hours before in winter. The moisture of the air indicates rain to a slight extent only.

In spring and autumn cirrus clouds moving from the northwest often precede rain twenty-four to forty-eight hours. In winter cirrus clouds from the northwest, and sometimes from the south, precede rain about twenty-four hours. Cirro-cumulus changing rapidly to alto-stratus clouds indicate rain in winter.

In spring and summer high west to north winds come with rising barometer, and in autumn high west winds attend rising and high barometric pressure. In winter high southeast winds occur with falling barometer.

Abnormally high temperature is of rare occurrence and usually comes with northerly winds. No low temperatures are experienced.

Late spring frosts in March and April damage the buds of deciduous fruits. Frosts of December, January, and February damage ripe citrus fruit.

Heavy frost is likely to occur with barometer above 30 and stationary or rising, temperature falling to 40° or below, northerly winds, and clear weather.

The general distribution of barometric pressure that is favorable for frost in California is low barometric pressure over southern California and southern Arizona and high barometric pressure over the middle and northern Rocky Mountain and plateau districts.

SAN LUIS OBISPO, CAL.

In spring, autumn, and winter precipitation is usually preceded twenty-four to forty-eight hours by southerly winds and falling barometer, and rain generally begins about the time of the turn in the barometer from falling to rising. As a rule the barometer falls to 29.95 or below in spring and winter and to 30 or below in autumn before rain begins. After falling, the barometer rises during rain until clearing weather occurs.

Owing to the proximity of this station to the sea the humidity of the air affords but a slight indication of approaching rains. A decrease in relative humidity is, however, sometimes noted twenty-four to thirty-six hours before rain.

Cirro-stratus clouds moving from points between south and west often precede rain about forty-eight hours. A thin blanket of lead-colored cirro-stratus clouds slowly spreading and finally covering the sky may be obscured in a few hours.

High winds come with rising barometer and from westerly points in spring, and from north or west in summer, autumn, and winter.

The warmer winds of all seasons come from the north, and also the cooler winds, except in summer, when the cool winds are from westerly.

Frost is likely to damage fruit in the spring.

Heavy frost usually attends high barometric pressure, temperature falling to 40° or below, high relative humidity, northerly winds, and a few cirrus clouds.

Frost is generally followed by rain within forty-eight hours.

SANTA FE, N. MEX.

Generally throughout the year steadily falling barometer with southerly winds for one to two days indicate precipitation, but precipitation seldom begins until after the turn in the barometer from falling to rising, and the wind has shifted from southerly to colder north and northeast. In summer the conditions that precede rain are not so well marked as during the winter months.

In winter and spring the relative humidity often increases during the twenty-four hours before precipitation, while in summer and autumn an increase in relative humidity is noted only immediately preceding the beginning of rain.

In spring and winter precipitation is usually preceded thirty-six to forty-eight hours by cirrus clouds moving from the west or southwest. The presence of cirrus clouds does not, however, necessarily indicate precipitation.

The highest winds of winter and spring are from northerly and westerly, and of summer and autumn from southerly and westerly.

In all seasons south to southwest winds prevail during periods of abnormally high temperature, and north to northeast winds during periods of abnormally low temperature.

Frost is likely to damage fruit or other crops from April 1 to May 15, and from October 1 to November 15.

The general conditions which precede heavy frost are low barometer, high temperature and humidity, and southerly winds, followed by rising barometer, falling temperature, and winds shifting to north and northeast, bringing snow on adjacent mountains.

SAVANNAH, GA.

In spring and winter south to southwest winds and falling barometer precede precipitation twenty-four to thirty hours. In summer rain is preceded about twenty-four hours by southwest winds and falling barometer, and in autumn about twenty-four hours by southerly or easterly winds and falling barometer. In all seasons the barometer generally falls to 30 or below before precipitation begins.

While, as a rule, increasing moisture is shown twelve to twenty-four hours in advance of rain in the warmer, and twenty-four to thirty-six hours in advance during the colder months, it is not believed that the humidity of the air at this, a seacoast station, possesses special value as an indicator of rain.

In well-defined rain periods, due to more or less pronounced storm areas moving across the country, cirro-stratus clouds, moving from the west in spring, summer, and winter, and from the southwest in autumn, precede precipitation for an average period of about twenty-four hours. At times the cirro-stratus clouds are followed by alto-stratus, and more frequently by alto-cumulus, clouds.

High winds generally come from south and east quadrants with falling, and from west and north quadrants with rising, barometer.

The warmer winds of spring and winter come from south and southwest, of summer from southwest, and of autumn from northeast. The cold winds of spring are from northwest to north, of summer and autumn from the northeast, and of winter from west, northwest, north, and northeast.

The critical period for damage by frost is during the months of March and April.

As a rule, the barometer is high and rising slowly twelve to twenty-four hours in advance of the occurrence of heavy frost, showing the near approach of a crest of high barometric pressure. On the day preceding frost the maximum temperature seldom exceeds 55°, with cloudless sky, light to fresh northwest wind, and relative humidity rather lower than usual. These general conditions appear both in spring and autumn.

SAULT STE. MARIE, MICH.

In all seasons precipitation is preceded twelve to eighteen hours by south to southeast winds and falling barometer, and the barometer usually falls to 29.90 or below before precipitation begins. In the case of storms from the south or southwest, however, precipitation often begins with higher barometer and shortly after the wind sets in from the northeast.

No note has been made by the observer of the relation between atmospheric moisture and precipitation. Neither has the relation between cloud formation and movements been noted.

The high winds of this station usually come from the northwest with rising barometer.

The warm winds come from the south and east in spring, autumn, and winter, and from southeast to southwest in summer. The cold winds of spring, summer, and autumn come from the northwest, and of winter from northwest to northeast.

Frost is likely to damage fruit or vegetables after May 20 and before September 20.

Heavy frost is usually preceded by barometer normal or above, temperature falling to 34° or 36°, average humidity, light west to north winds, and clear sky.

SCRANTON, PA.

Precipitation is usually preceded twelve to twenty-four hours by winds from points between south and northeast and falling barometer, and the barometer generally falls to 30 or below before precipitation begins. In connection with storms that advance from the south or southwest, precipitation often closely follows the shift of the wind to northeast and the turn in the barometer from rising to falling.

There is usually an increase in relative humidity eight to twelve hours before precipitation begins.

Cirrus and cirro-stratus clouds moving from a westerly direction generally indicate precipitation within twelve to eighteen hours.

The warm winds of all seasons come from south or southwest, and the cold winds from northwest and north.

Frost is likely to damage vegetation early in May and late in September and early in October.

Heavy frost is usually preceded by slowly rising and high barometer, temperature falling to 40° or below, low relative humidity, light west to north winds, and clear sky.

SEATTLE, WASH.

Southeast to southwest winds usually precede precipitation six to eighteen hours in spring, twelve to thirty-six hours in summer, twelve to eighteen hours in autumn, and six to twelve hours in winter.

A steady fall in the barometer to quite a distance below the normal is considered an indication of rain, and, as a rule, the greater the fall in the barometer the heavier the rain. In spring rain generally begins after the barometer begins to rise after a marked fall, in summer about the time the barometer has reached the lowest point, and in autumn and winter usually while the barometer is falling. The height of the barometer when rain begins varies with the position and distance of the storm center and the amount of the central depression. A gradual rise above the normal barometer is an indication of fair weather. A rapid rise in the barometer does not indicate settled weather.

As the air is always moist the relative humidity does not afford an indication of weather changes, except that a decrease is sometimes noted twenty-four to forty-eight hours before rain in summer and twelve to eighteen hours before rain in autumn. In autumn also an excess of moisture in the air causes dense fog.

In spring and autumn cirro-stratus clouds moving from west or northwest precede rain twelve to twenty-four hours. In winter cirro-stratus clouds are quickly followed by a veil or bank of stratus or strato-cumulus and then rain follows usually in six to twelve hours. In summer the indications of cirro-stratus are not so reliable. A leaden-colored veil of stratus clouds first appearing in the south and gradually spreading toward the zenith presages rain at all seasons. Mount Rainier, 65 miles SSE., is early obscured. Clear visibility of Rainier in the afternoon is a sure sign of fair weather for about twenty-four hours.

High winds come from the south and southeast with falling, and from southwest to northwest—and sometimes in winter from north and northeast—with rising, barometer.

The warm winds of spring are from the north, of summer and autumn from northwest and north, and of winter from south and southwest. The cold winds of spring and autumn are from northeast, of summer from south, and of winter from northeast to north.

Frost will cause damage in the latter part of March and the first ten days in April, when fruit trees are generally in bloom; apples sometimes bloom as late as the third decade of April, but usually by the 10th. Tender vines are damaged by frost in May, and late vegetables in September and early October.

Heavy frost is usually indicated by barometer rising rapidly and high for the season, falling temperature, low relative humidity, west to northwest winds, high cumulus or cirro-cumulus clouds from the northwest rapidly dissolving or clearing away, and a crisp feeling in the atmosphere.

SHREVEPORT, LA.

Precipitation is preceded one to three days by south or southeast winds and falling barometer, and the barometer usually falls to about 29.90 or below in spring, and to 30 or below in summer, autumn, and winter, before precipitation begins. In all seasons except winter precipitation does not generally begin until after the turn in the barometer from falling to rising. In the colder months northeast winds often precede rain.

As near as could be ascertained from the records, there is an increase in relative humidity twenty-four to forty-eight hours in advance of precipitation; at times, however, there has been a decrease in relative humidity preceding precipitation.

Cirro-stratus clouds moving from the west seem to precede the beginning of precipitation for an average period of about thirty-six hours, and alto-cumulus clouds moving from the south often precede rain about twelve hours.

High winds come from south and southeast with falling, and from northwest with rising, barometer.

The warm winds of all seasons come from the southeast, and the cold winds from the northwest.

Frost is likely to cause damage in April, May, September, and October.

Heavy frost is usually preceded by rising barometer, falling temperature, decreasing relative humidity in spring and autumn, and increasing in winter, light northwest to north winds, and lower clouds clearing away. In 75 per cent of the cases examined rain had fallen within forty-eight hours preceding the occurrence of frost.

SIOUX CITY, IOWA.

Precipitation is usually preceded twelve to twenty-four hours by southeast to northeast winds and falling barometer, and the barometer generally falls to 29.90 or below before precipitation begins. In spring and summer rain begins while the barometer is falling, and in autumn and winter after the turn in the barometer from falling to rising.

An increase in relative humidity usually occurs twelve to twenty-four hours before precipitation, but the cases are common when a decrease occurs during the same period.

Cirro-stratus clouds advance from the west during the warmer, and from the northwest during the colder, months. No relation between the appearance of these or other cloud forms and precipitation has, however, been established.

During periods of abnormally high temperature the winds come from south in spring and autumn, and from south and southwest in summer and winter. The cold winds of all seasons come from northwest and north.

Frost is likely to damage tender vegetation after May 1, and before September 30.

The conditions that precede frost are, rising barometer, temperature falling to 40° or below, low relative humidity, and clearing sky.

SPRINGFIELD, ILL.

Precipitation is usually preceded twelve to twenty-four hours by winds that set in from points between south and east—and sometimes from northeast during the colder months—and falling barometer, and the barometer generally falls to 30 or below before precipitation begins. Precipitation usually begins while the barometer is falling, except during the warm months, when showers often begin about the time of the turn in the barometer from falling to rising.

There is generally an increase in relative humidity about twenty-four hours before precipitation, but the increase appears to be less marked in summer than during the colder months. In general a high dew-point indicates rain, but rain often quickly follows a low dew-point.

Cirro-stratus and cirrus clouds are generally considered forerunners of precipitation, when other conditions are favorable. When these clouds appear during the day, precipitation is likely to begin during the night; and when they are observed in the morning, rain begins in the afternoon.

The warm winds come most frequently from south and southwest, and the cold winds from northwest, except in summer, when they come from the northeast.

Frost is most likely to damage fruit or other crops in April, May, September, and October.

Heavy frost is usually preceded by rising and high barometer, falling temperature, low relative humidity, light winds, and clear or clearing weather.

SPRINGFIELD, MO.

Precipitation is preceded twelve to thirty-six hours by southeast to east winds and falling barometer, and the barometer usually falls to 29.90 or below in spring, to 29.95 or below in summer and autumn, and to 30 or below in winter before precipitation begins. In all seasons precipitation generally begins with falling barometer, except during the warmer months, when showers begin with the turn in the barometer from falling to rising.

During the colder months there is generally an increase in atmospheric moisture twenty-four hours before precipitation. In summer excessive moisture, as indicated by a muggy and oppressive condition of the air, is a good indication of thunderstorms.

Cirrus and cirro-stratus clouds moving from the west in spring and autumn, from southwest or west in summer, and from west or northwest in winter often precede precipitation twenty-four to thirty-six hours. Cirrus followed by alto-stratus clouds, increasing in density, indicate rain; also rapidly moving scud stratus in the morning. Cumulus banking in the west or northwest in the evening are a good indication of rain; and also alto-stratus changing to stratus and becoming denser.

The warmer winds of spring and winter come from south and southeast, of summer from south, and of autumn from south to southwest. The colder winds of all seasons come from points between west and north.

Frost is likely to cause damage about the middle of April and early in October.

Heavy frost is usually preceded by high or rising barometer, temperature about 40° at the evening observation, low relative humidity, light northwest to north winds, and clear weather.

SPOKANE, WASH.

Precipitation is generally preceded twelve to forty-eight hours by southeast to southwest winds and falling barometer, and the barometer usually falls to 29.90 or below before precipitation begins. In all seasons, except summer, precipitation generally begins with falling barometer.

An increase of relative humidity has been observed twenty-four to forty-eight hours before precipitation; at other times the relative humidity has seemingly decreased, but as observations of the humidity are made in general only at twelve-hour intervals it is believed that an increase in humidity preceding precipitation is often unobserved.

Cirro-stratus clouds advance from the southwest, and the average interval between their first appearance and the beginning of precipitation, when precipitation follows, is about twenty-four hours; the cirro-stratus cloud formation is, however, seldom observed at this station. When conditions are becoming favorable for rain, stratus or strato-cumulus are generally the clouds that immediately precede or indicate rain. Cirrus clouds may be observed for days at a time in summer and autumn before rain, and more often no rain will follow. At times, and particularly in winter and spring, a sheet of stratus assumes a baggy, greasy appearance, resembling the festoons that precede thunderstorms, but on a larger scale; this formation is considered a good indication of precipitation. If stratus clouds move from a southerly direction precipitation is expected within twenty-four hours. In winter there sometimes appears a thin stratus formation, resembling cirro-stratus, through which the sun may be seen, but without halo; this formation is considered an indication of snow, when moving from a southerly direction.

High winds usually occur a few hours before the barometer reaches its lowest point, and continue after the barometer begins to rise, shifting from southwest to west.

The warm winds of spring and winter come from south and southwest, and of summer and autumn from east to northeast. The cold winds come from east and northeast in spring and winter, and from southwest to west in summer and early autumn.

From April 1 to May 15 is the most critical time for damage to fruit by frost; and also the period between October 15 and November 15, when the winter apple, which is the staple fruit of this section, is subject to damage.

Barometer above the normal and a clear sky precede heavy frosts. The evening before frost occurs the temperature may be as high as 60°, and the relative humidity about 50 per cent, and with pressure and weather conditions favorable frost will occur. At such times the temperature will fall during the night to near 32°, and the relative humidity becomes high, often 100 per cent. Although the heavier frosts seem to come with the wind from points between north and northeast, light winds from other directions occur when other conditions favor their occurrence.

TACOMA, WASH.

South to southwest winds and falling barometer usually precede precipitation six to eighteen hours, and the barometer generally falls to 29.90 or below before precipitation begins. Rapidly falling barometer with a storm central off the coast of Vancouver Island furnish conditions favorable for heavy rain. Rising barometer with wind shifting to westerly indicate clearing weather. High and steady barometer indicates continued fair weather.

Humidity is usually very high in the Puget Sound region, and the observations taken do not afford sufficient data for a deduction of facts regarding the relation of atmospheric moisture and rain. The relative humidity is frequently low during rain, and again 100 per cent of relative humidity is sometimes unaccompanied by rain.

Owing to the regularity of the "wet" and "dry" seasons but little dependence can be placed on cloud observations. During the "dry" season the observation is always "smoke" or "stratus," and in the winter it is nearly always "stratus" or "nimbus." Cirro-stratus clouds, when observed, advance from points between southwest and northwest.

The high winds of this station usually come from the southwest with rising barometer, except when storm centers pass to the south, when north to east gales are experienced.

The warm winds of spring and winter come from south and southwest, and of summer and autumn from the north. The cold winds of all seasons come from the north.

Frost is likely to cause damage in March and April, when fruit trees are in bloom. All crops and fruits are harvested long before the first killing frost in the autumn or winter. The observer's experience here leads him to believe that much of the damage to fruit that is attributed to frost is really caused by cool, rainy weather, which prevents the flight of bees and other insects, upon which the fruit blossoms have to rely for the act of fertilization.

Conditions for the occurrence of frost are, high barometer, falling temperature, average humidity, light winds, and clear weather.

TAMPA, FLA.

In spring rain is usually preceded three to twelve hours by southwest winds and falling barometer and begins on the turn of the barometer from falling to rising. Summer is the wet season, and rain is generally preceded for a variable period by southeast winds and begins about the time of the turn in the barometer from falling to rising. In autumn northeast winds and falling barometer usually precede rain three to twelve hours, and rain begins when the barometer has reached the lowest point and is on the upward turn; rain often occurs without visible premonitory indications, and again in anticyclonic areas on the turn in the barometer from rising to falling. In winter southerly winds and falling barometer usually precede rain three to twelve hours, and rain begins while the barometer is falling and sometimes continues with west to northwest winds and rising barometer. While the barometer generally falls to 29.90 or below in spring and summer, and to 30 or below in autumn and winter before rain begins, rain will occur with any abnormal change or height of the barometer.

The relative humidity increases one to three hours before rain, but a high percentage of relative humidity is not necessarily an indication of rain.

Cirrus and cirro-stratus clouds are occasionally observed moving from a westerly direction in spring, summer, and winter, but, except at times in summer, afford no indication of rain.

High winds come from south to east points with falling, and from west and northwest with rising, barometer.

The warm winds of spring come from the southeast, of summer from south to southeast, of autumn from the northeast, and of winter from east to south points. The cold winds of spring, summer, and autumn come from the north, and of winter from northwest and north.

Frost is likely to damage fruit or other crops from November 15 to April 15.

In autumn and winter heavy frost is preceded by barometric pressure rising to 30.20 or above, temperature 50° or below, relative humidity between 70 and 80 per cent in autumn and between 60 and 80 per cent in winter, light northwest winds, and clear weather or a few upper clouds.

TOLEDO, OHIO.

Precipitation is preceded twelve to twenty-four hours by southerly to easterly winds and falling barometer, and the barometer usually falls to about 29.85 or below before precipitation begins. When storms advance from the south or southwest precipitation often begins closely following a shift of wind to the northeast and the turn in the barometer from rising to falling.

While there is an increase of relative humidity preceding precipitation when winds are from the easterly, a decrease occurs with winds from southerly quarters. When the wind shifts from southerly to cooler easterly preceding rain the relative humidity increases. In itself the relative humidity can not be considered an indicator of precipitation.

Cirrus and cirro-stratus clouds are always observed moving from a westerly direction, and often appear eight to thirty-six hours in advance of precipitation. Clouds of this formation thicken rapidly and merge into lower clouds preceding precipitation.

High winds come from south and southwest with falling, and from west and northwest with rising, barometer.

The warm winds of spring come from south and west, of summer from southwest, and of autumn and winter from south and southwest. The cold winds of spring come from northwest to northeast, of summer from north to northeast, of autumn from west to northwest, and of winter from southwest to northwest.

Frost is likely to damage fruit or other crops from about April 15 to May 20 and during September.

The conditions that precede heavy frost are high barometer, low temperature for the season, low relative humidity at preceding observation, light winds, and clear weather.

VALENTINE, NEBR.

Southeast to east winds and falling barometer generally precede precipitation twelve to forty-eight hours, and the barometer usually falls to 29.80 or below in spring, to 29.90 or below in summer, and to 30 or below in autumn and winter before precipitation begins. In spring and winter, precipitation begins after the turn in the barometer from falling to rising, and in summer and autumn about the time the barometer begins to rise after a fall. In a majority of cases precipitation does not follow either a rapid fall or rise in the barometer. A slow and steady fall in the barometer, with an unsettled appearance of weather conditions, more often precedes precipitation.

In all seasons an increase in relative humidity begins twenty-four to thirty-six hours before precipitation, and a decrease occurs just before precipitation begins. A high percentage of relative humidity does not necessarily indicate precipitation.

Cirrus and cirro-stratus clouds move from the west and northwest, but can not be depended upon as indicators of precipitation. In summer large masses of ominous looking strato-cumulus clouds moving swiftly from the southwest, west, or northwest precede rain; and in autumn heavy masses of cumulus, if they last until afternoon, will sometimes cause heavy showers. In winter, precipitation is often preceded by cirro-cumulus clouds followed by a gradually thickening veil of low stratus, which moves very slowly.

High winds generally start in from southerly and shift to west and northwest with rising barometer.

The warm winds of all seasons blow from points between south and west, and the cold winds from northwest and north, and in winter from points between northwest and northeast.

Frost is likely to cause damage after May 1.

In spring frost is generally preceded by rising barometer, temperature below normal, and relative humidity increasing to 80 or 90 per cent. In autumn, frost generally occurs after a long cloudy spell, with or without precipitation, with rising barometer, temperature falling to 38° or below, high relative humidity, west to northwest winds, and clear or clearing weather.

VICKSBURG, MISS.

Precipitation is usually preceded six to thirty-six hours by south to southeast winds and falling barometer, and the barometer generally falls to about 29.95 or below in spring and autumn, to 29.90 or below in summer, and to 30 or below in winter before precipitation begins.

During the colder months there is generally a slight increase in relative humidity during a period of about six hours before precipitation begins, and during the warmer months there is a slight decrease during a corresponding period.

Cirrus and cirro-stratus clouds move from the west, and when precipitation can be associated with their appearance it occurs two to three days after they appear. No other characteristics of cloud formation that presage rain have been noted by the observer.

The warm winds of all seasons come from south and southeast. The cold winds of spring, autumn, and winter are northeasterly, and of summer easterly.

Frost is likely to damage fruit or other crops in March, April, and October.

Twenty-four hours preceding frost the barometer generally ranges near or above 30.30 over northern Texas and higher to the westward or northward, with the 40° isotherm dipping well into Texas. Frequently heavy rainfall occurs within forty-eight hours preceding heavy frost. Light northerly winds attended by clear or clearing weather and decreasing humidity usually prevail during twenty-four hours preceding heavy frost.

WALLA WALLA, WASH.

Precipitation is generally preceded four to six hours by southerly winds and falling barometer, and the barometer generally falls to 29.90 or below before precipitation begins. In spring, autumn, and winter precipitation begins on a falling barometer, and in summer on the turn in the barometer from falling to rising. The barometer generally falls rapidly preceding rain.

There is, as a rule, a slight increase in relative humidity three to four hours preceding precipitation.

Cirrus and cirro-stratus clouds moving from a westerly direction usually presage precipitation within twenty-four to thirty-six hours, and precipitation is immediately preceded by stratus clouds moving rapidly from the south or southwest.

The high winds of all seasons come from the southwest with falling barometer.

The warm winds of spring come from the southwest, of summer from south and southwest, and of autumn and winter from the south. The cold winds of spring come from the south, of summer from the northeast, of autumn from the north, and of winter from the southeast.

Frost is likely to cause damage from about the middle of April to the early part of June.

Heavy frost is preceded by barometer above the normal, temperature falling to 40° or below, high relative humidity, light easterly winds, and few, if any, clouds.

WASHINGTON, D. C.

In connection with areas of low barometric pressure that advance to the Atlantic coast from the west or west-northwest the wind sets in from the southeast quadrant with falling barometer twelve to thirty-six hours before precipitation begins, and the barometer usually falls to 30 or below before the beginning of precipitation. In connection with areas of low barometer that advance from the south or southwest precipitation frequently begins closely following the shift of wind to the northeast, and often with high but falling barometer; this is particularly the case during the colder months, when moisture contained in the comparatively warm easterly winds from the ocean is condensed by the lower temperatures of the interior.

The easterly winds that precede precipitation are of a necessity moist winds, and the humidity of the air increases when the wind sets in from these quarters. During the colder months increasing humidity is therefore an indication of precipitation when the increase is attended by falling barometer. During the summer months, also, an increase in humidity to indicate rain must be attended by barometric conditions that attend an approaching area of low barometer.

Cirrus and cirro-stratus clouds move from westerly directions and are, as a rule, forerunners for periods of twelve to eighteen hours of precipitation. The appearance of these clouds indicates a barometric disturbance to the westward; they do not, however, invariably indicate precipitation; at times the barometric disturbance will not possess sufficient strength to cause precipitation. Cirrus and cirro-stratus clouds that precede precipitation gradually thicken and merge into alto-stratus and finally into stratus clouds that assume the direction of the surface wind. Other cloud formations, such as summer cumulus, that precede precipitation are rain-carrying clouds when barometric and wind conditions favor rain, and do not appear sufficiently in advance of precipitation to be of value in forecasting.

The high winds of all seasons are generally from southerly shifting to westerly with rising barometer. In connection with southern storms, however, gales of exceptional violence sometimes come from the east quadrants.

During periods of abnormally high temperature the wind generally comes from points between south and west. The cold winds of late spring come from the northeast quadrant; in other seasons the cold winds come from the northwest.

Frost is likely to damage fruit or other tender crops during April and the early part of May, and from late in September through October.

Heavy frost in spring and autumn is preceded by barometer above the normal or rising rapidly, temperature falling to 40° or below, decreasing relative humidity, clear or clearing weather, and light winds from westerly quarters.

WICHITA, KANS.

Precipitation is usually preceded twelve to twenty-four hours by winds from points between south and east and falling barometer, and the barometer generally falls to 29.90 or below in spring to 29.80 or below in summer and autumn and to 30 or below in winter before precipitation begins. In all seasons precipitation begins, as a rule, on falling barometer, but during the late autumn, early spring, and winter months the beginning of precipitation is sometimes delayed until after the turn in the barometer from falling to rising. At such times the wind goes to north quadrants before the beginning of precipitation attending the passage of a storm center south of the station.

In summer and autumn there is a marked decrease in relative humidity twelve to twenty-four hours before rain. During the colder months the change in the moisture of the air preceding precipitation is not marked.

Precipitation does not always follow the appearance of cirrus or cirro-stratus clouds, but when it does the interval between the appearance of these clouds and the beginning of precipitation varies in length from eighteen to twenty-four hours. The cirro-stratus clouds gradually cover the whole sky, becoming denser, and merge into clouds of alto-stratus and stratus formation.

The highest winds of all seasons come from northerly quadrants with rising barometer.

The warm winds come from the south and from a little west of south, but not from the southwest. The cold winds of all seasons come from the north.

Frost is likely to cause damage as early as March 25, but generally from April 1 to May 15. Damage is rarely caused by fall frosts.

The conditions that favor the occurrence of frost are, barometer above 30, temperature falling to 36° or below, relative humidity 80 per cent or more, clear weather, and little or no wind.

WILMINGTON, N. C.

Precipitation is preceded twelve to thirty-six hours by winds from points between southeast and northeast and falling barometer, and the barometer generally falls to 30 or below before precipitation begins. At times, however, when the wind sets in from the northeast during the colder months, the interval is not so great and the barometer does not fall as low as stated.

Beyond the fact that "rain winds" are easterly winds and are necessarily moist winds, no definite relation between relative humidity and approaching rain has been discovered.

Cirrus and cirro-stratus clouds move from westerly and are considered forerunners of rain for an average period of about thirty-six hours.

High winds come from southwest and northeast with falling barometer.

The warm winds of all seasons come from the southwest, and the cold winds from the north.

Heavy frost in spring and autumn is preceded by barometer rising and above the normal, temperature falling to 40° or below, low relative humidity, clearing or clear weather, and light winds from the northwest quadrant.

WILLISTON, N. DAK.

Precipitation is usually preceded about twelve hours by southerly winds and falling barometer, and the barometer generally falls to about 29.80 or below in spring and summer to 29.90 or below in autumn and to 30 or below in winter before precipitation begins. In spring and autumn, precipitation usually begins on a falling barometer, in summer about the time of the turn in the barometer from falling to rising, and in winter on a rising barometer.

There is usually a slight decrease in relative humidity preceding precipitation, but the relation between changes in atmospheric moisture and precipitation have not been noted.

Cirro-stratus clouds from westerly quarters are considered indicators of precipitation, but the period of interval between their first appearance and the beginning of precipitation has not been observed.

The high winds of all seasons come from west, northwest, and north with rising barometer.

The warm winds of spring come from south and southwest, of summer and winter from points between south and west, and of autumn from south and southeast. The cold winds of all seasons come from northwest and north.

The soil products of this section are not subject to damage by frost, the only fruit grown being a few strawberries, and the principal crop, hay.

Frost will occur in the spring and fall when the temperature falls below 40°, with high barometer, high relative humidity, light northwest to north winds, and clear or clearing weather.

WINNEMUCCA, NEV.

In spring and summer, rain usually falls in the form of thunderstorms with westerly winds and is preceded about twenty-four hours by winds blowing from points between southeast and south. In autumn and winter, winds from south to southeast precede precipitation nine to twelve hours. In spring the barometer generally falls to 29.80 or below in summer to 29.75 or below and in late autumn and winter to 29.90 or below before precipitation begins.

Observations of the relative humidity of the air are not considered of value in forecasting, for, although decreasing atmospheric moisture in spring and summer indicates rain, and increasing humidity in autumn and winter indicates rain or snow, these changes occur so frequently without precipitation that they are of value in foreseeing storms only when considered in connection with other atmospheric conditions.

The sky in this dry climate is seldom free from upper clouds, but weeks will sometimes pass without rain. In the spring upper clouds from the south are often followed by rain in eighteen to twenty-four hours. In summer cumulus clouds from the southward that are met by clouds coming from another direction are frequently followed by showers and thunderstorms in twelve to fourteen hours. In autumn and winter, upper clouds from the north or northeast are generally followed by precipitation in twelve to eighteen hours. Cirrus and cirro-stratus clouds move from points between southwest and west.

The high winds of this station come from the southwest quadrant with falling barometer.

The warm winds of all seasons come from south to southwest points, and the cold winds from north and northeast.

Fruit is likely to be damaged by frost from April 15 to May 15, and garden produce from August 15 to September 15.

Frost is usually preceded by low but rapidly rising barometer, high and rapidly falling temperature, high relative humidity, and southerly winds with light rain followed by wind going to northerly.

YUMA, ARIZ.

While the barometer generally falls and the wind comes from south and east quadrants before precipitation the winds that immediately precede rain are squalls, entirely local, and of varying directions and intensity.

In summer and winter there is usually an increase in relative humidity three to six hours before rain. Increasing moisture in summer indicates showery conditions and precipitation in adjacent localities. In winter high humidity occurs, in the absence of wind, by reason of excessive evaporation from river and irrigated areas.

In summer cirrus clouds from the southwest sometimes precede showers two to six hours. In other seasons cirrus clouds appear moving from west or southwest, but the definite relation that may exist between the appearance of these clouds and conditions favorable for precipitation have not been determined.

The high winds of spring, autumn, and winter come from the north with rising barometer, and of summer from southeast shifting to southwest winds and rising barometer.

In this section frost will cause damage from the middle of December to the middle of February.

Heavy frost is preceded by rising barometer, temperature falling to 40° or below, low but increasing relative humidity, decreasing wind becoming very light, and clear weather.

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CHART I. FEBRUARY 4, 1903—8 A. M.

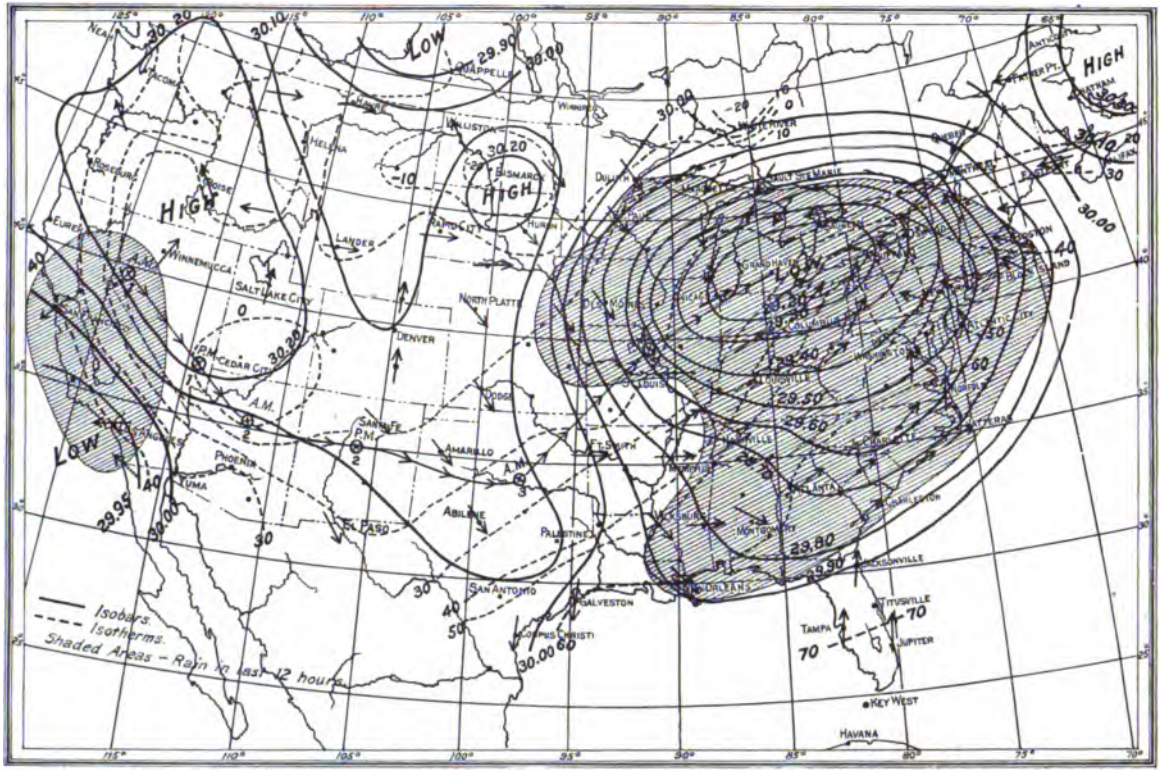


CHART II. RAIN WINDS. SPRING.

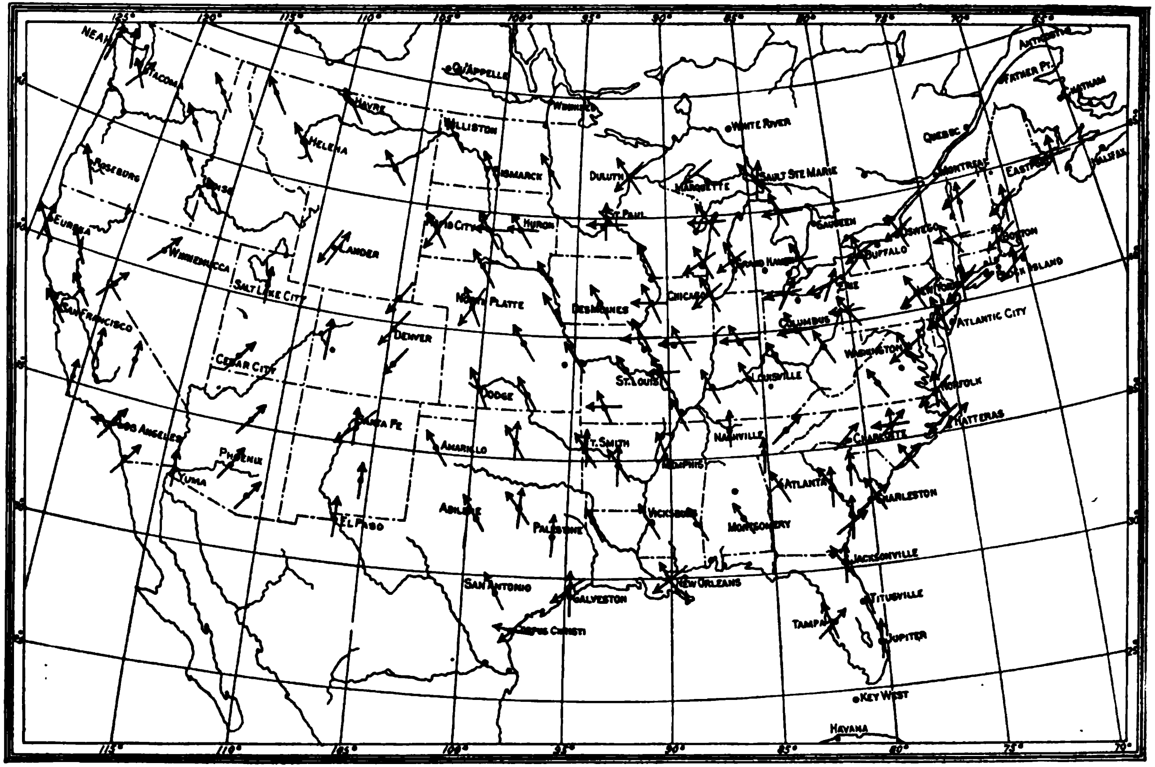


CHART III. RAIN WINDS. SUMMER.

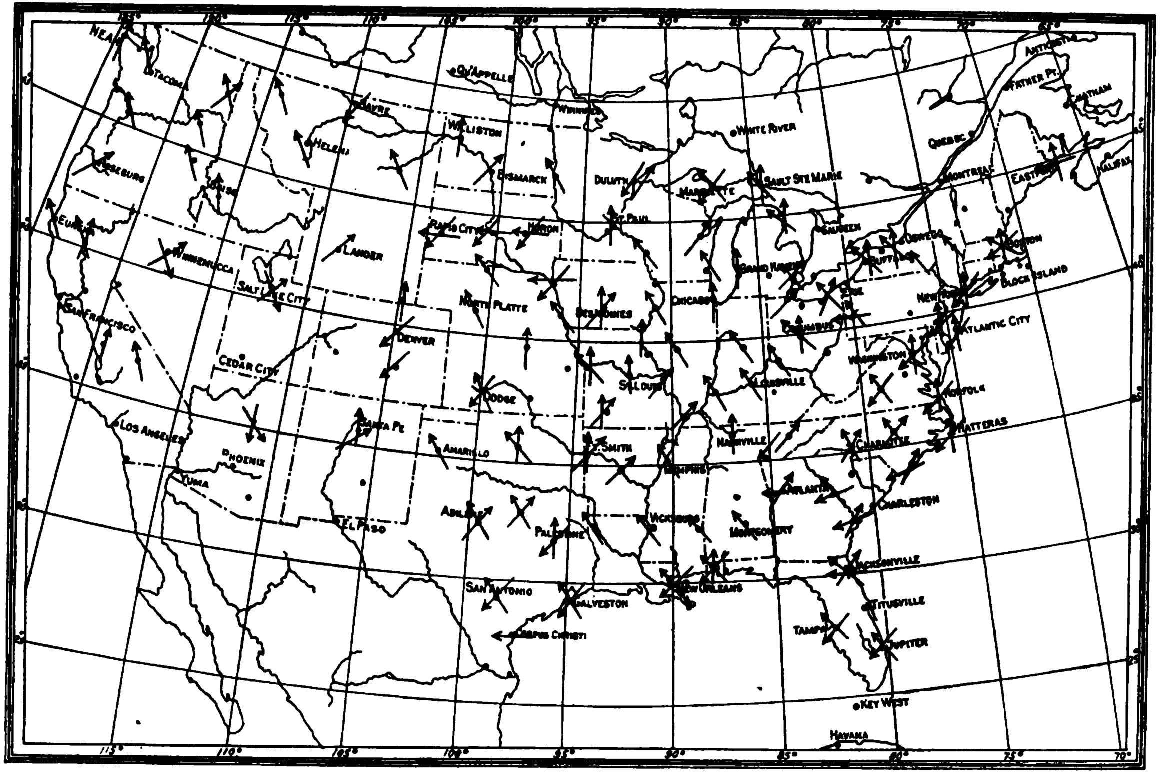


CHART IV. RAIN WINDS. AUTUMN.

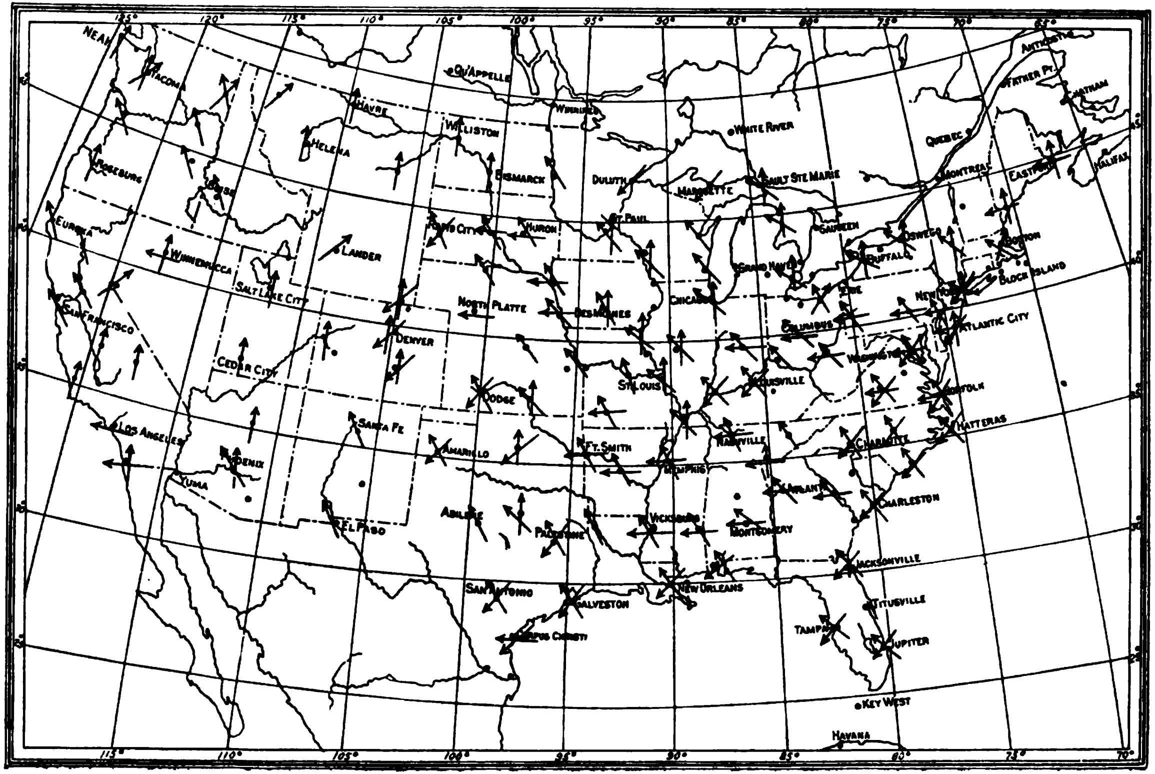


CHART V. RAIN WINDS. WINTER.

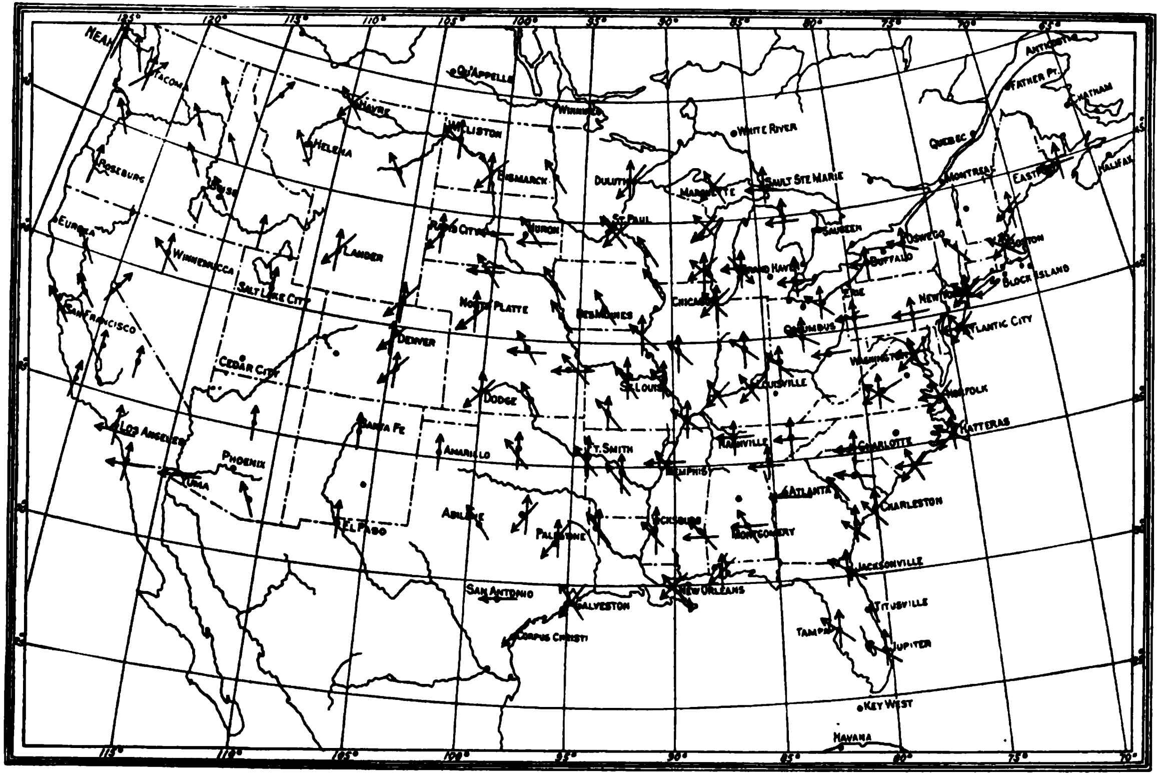
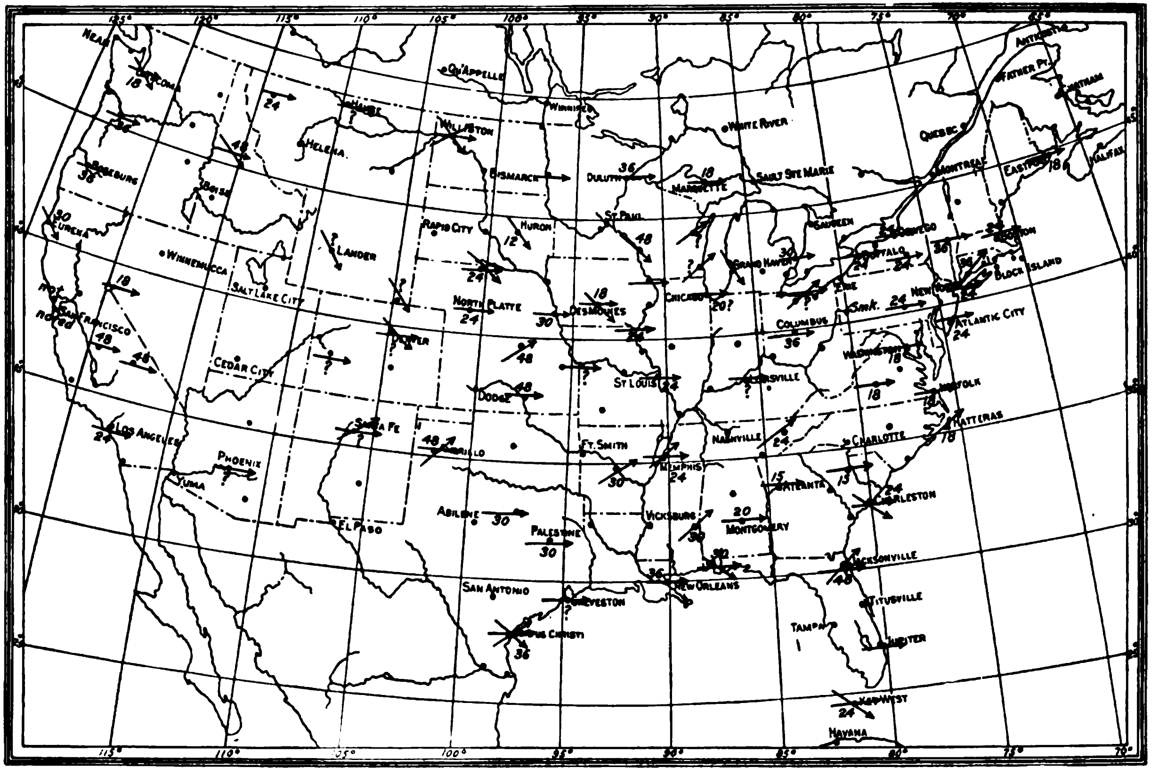
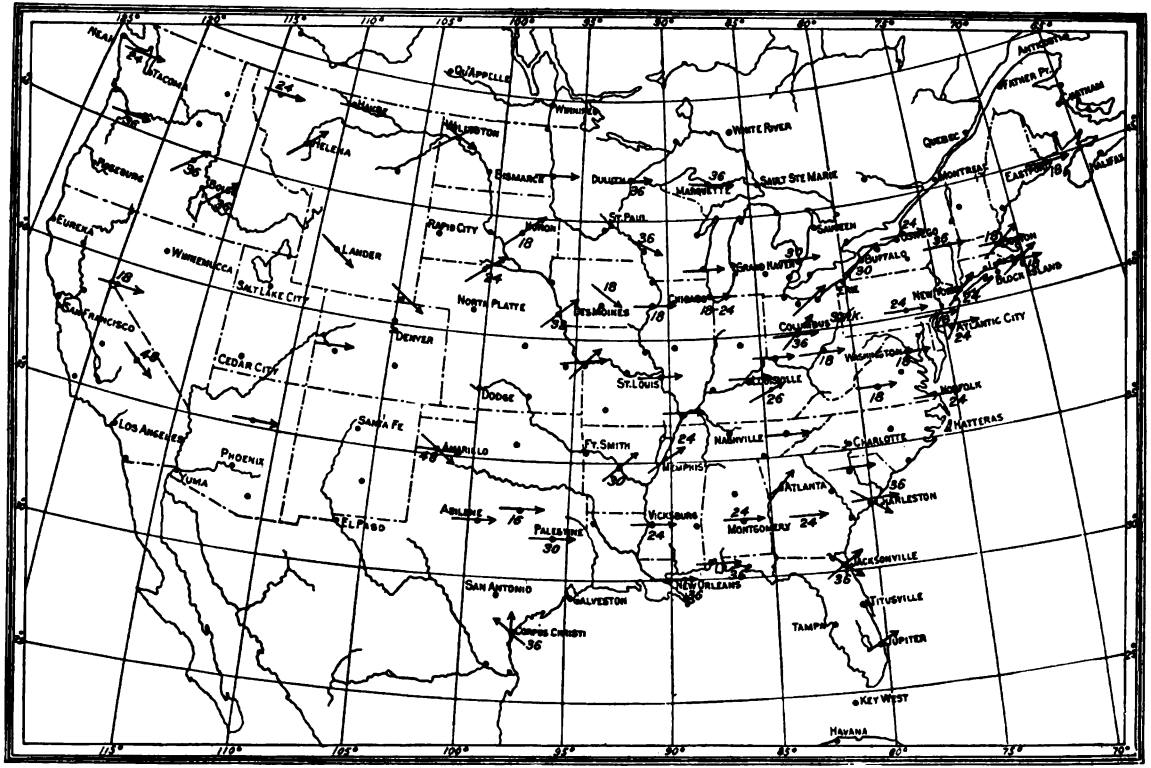


CHART VI. CIRRUS OR CIRRO-STRATUS CLOUDS BEFORE RAIN—DIRECTION AND TIME. SPRING.



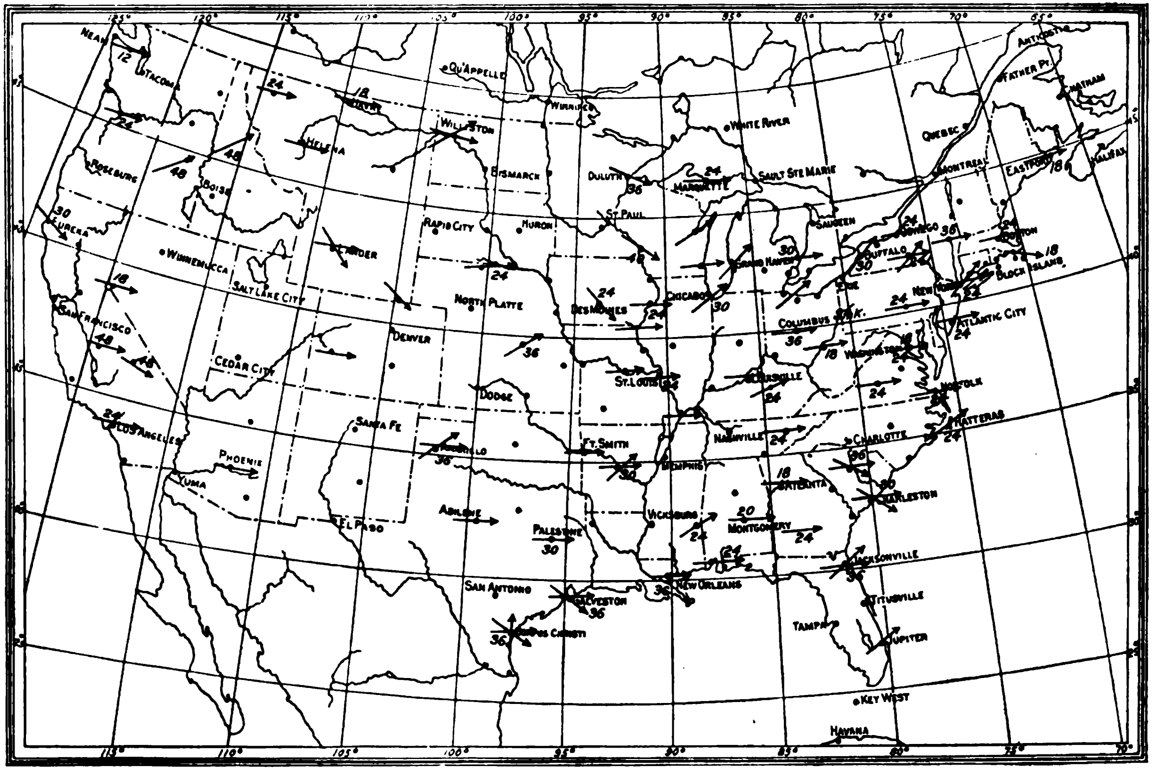
Figures indicate average number of hours clouds were observed before precipitation begins.

CHART VII. CIRRUS OR CIRRO-STRATUS CLOUDS BEFORE RAIN—DIRECTION AND TIME. SUMMER.



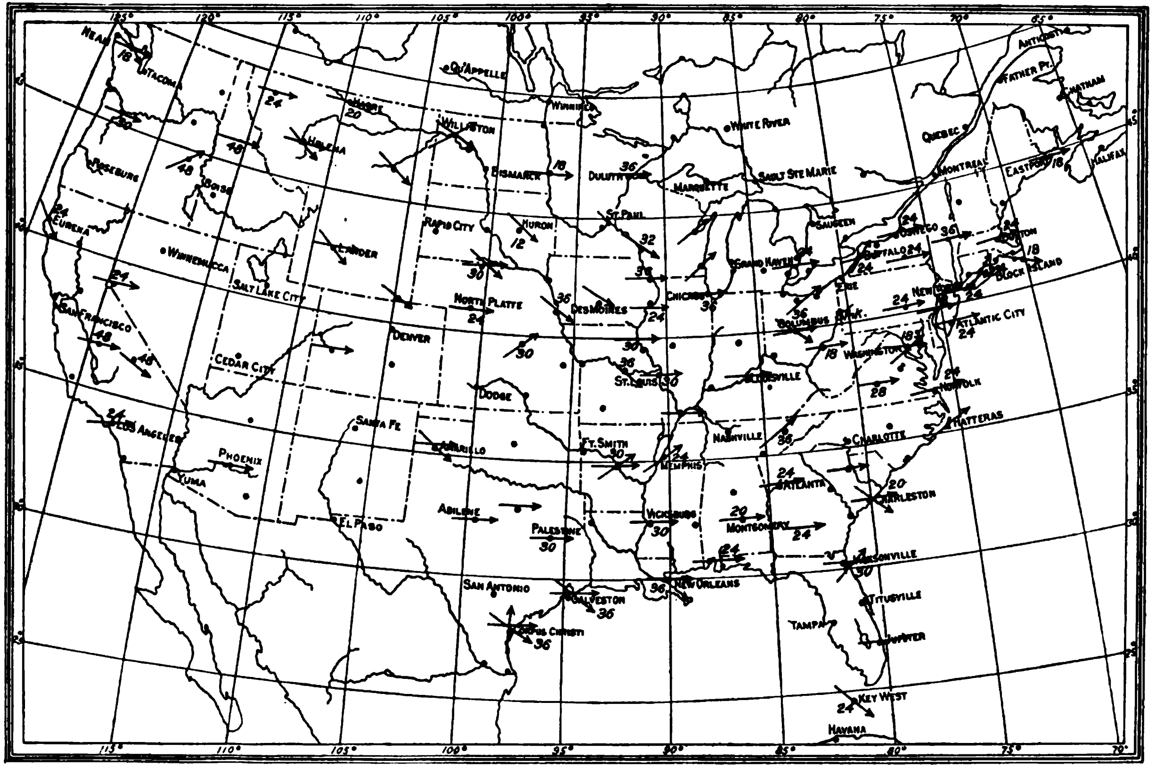
Figures indicate average number of hours clouds were observed before precipitation begins.

CHART VIII. CIRRUS OR CIRRO-STRATUS CLOUDS BEFORE RAIN—DIRECTION AND TIME. AUTUMN.



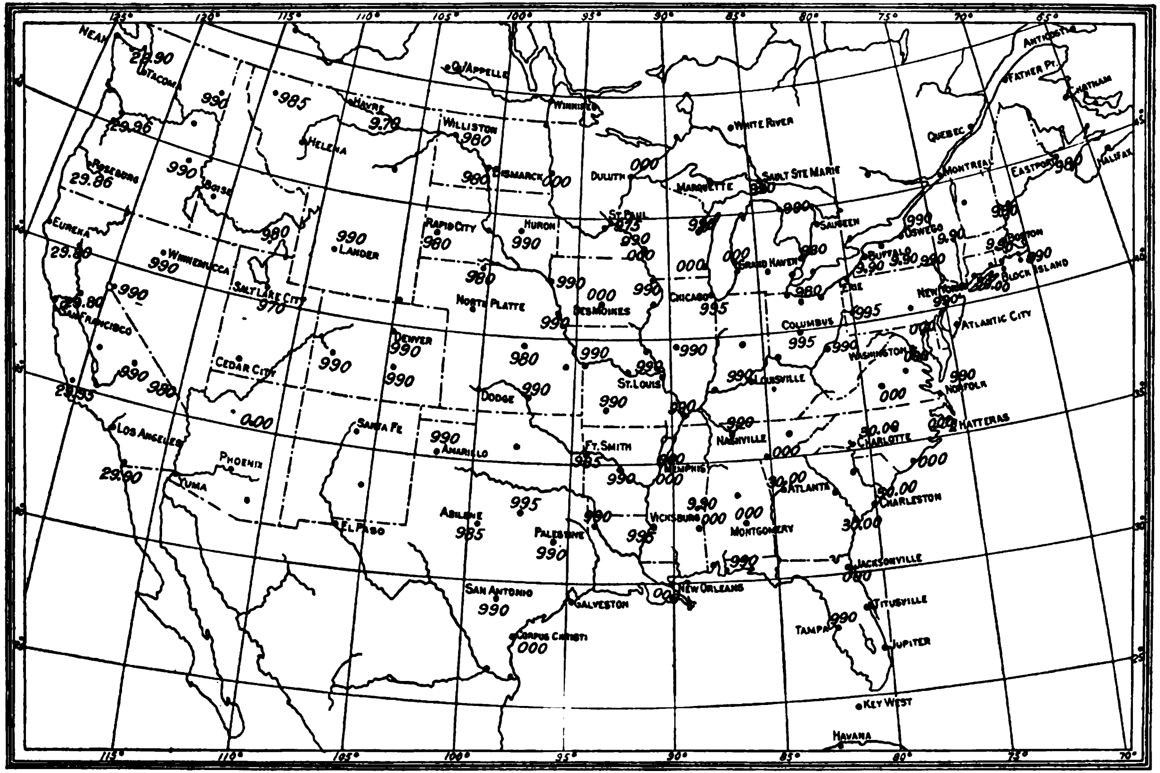
Figures indicate average number of hours clouds were observed before precipitation begins.

CHART IX. CIRRUS OR CIRRO-STRATUS CLOUDS BEFORE RAIN—DIRECTION AND TIME. WINTER.



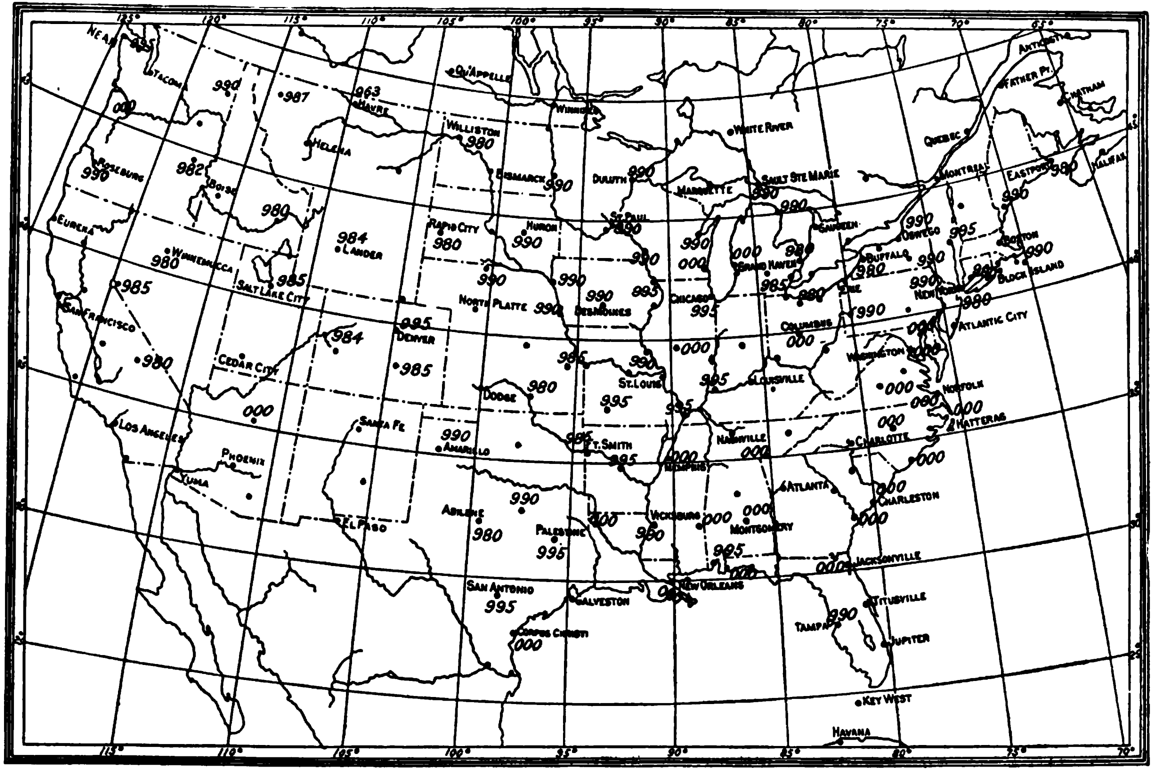
Figures indicate average number of hours clouds were observed before precipitation begins.

CHART X. BAROMETER HEIGHT PRECEDING PRECIPITATION. SPRING.



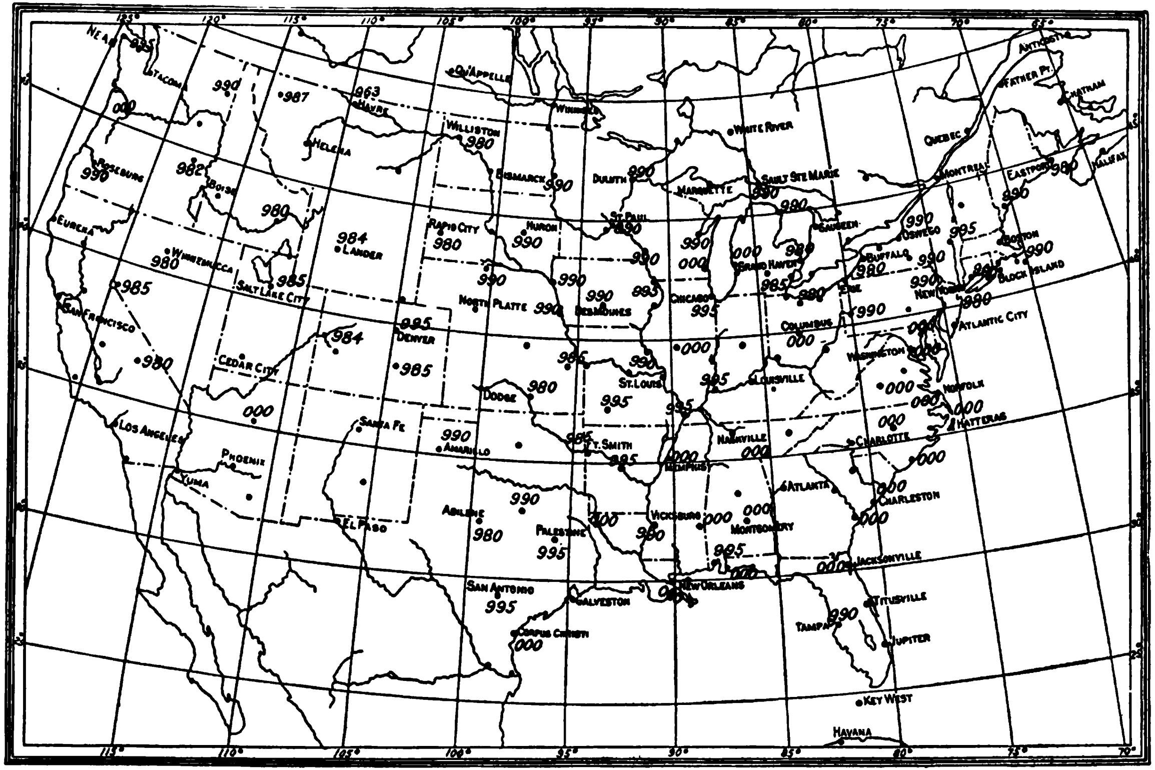
Figures indicate average number of hours clouds were observed before precipitation begins.

Chart XI. Barometer Height Preceding Precipitation. Summer.



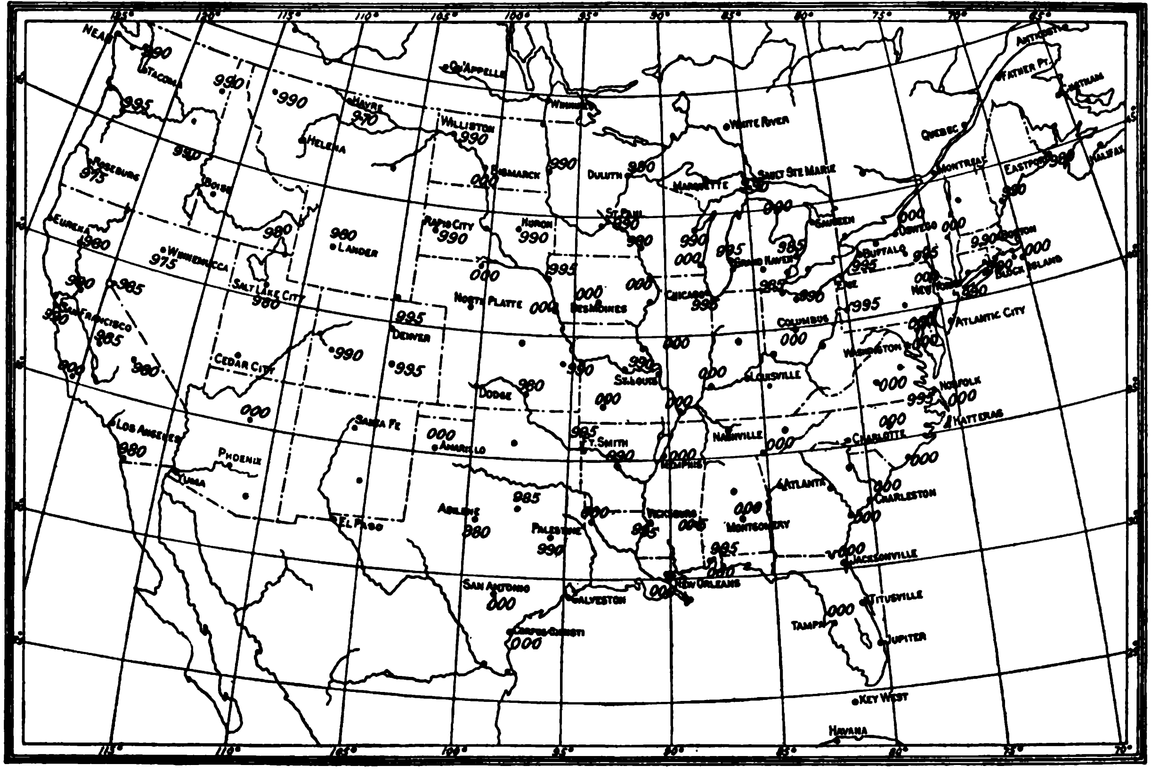
Figures indicate average number of hours clouds were observed before precipitation begins.

CHART XI. BAROMETER HEIGHT PRECEDING PRECIPITATION. SUMMER.



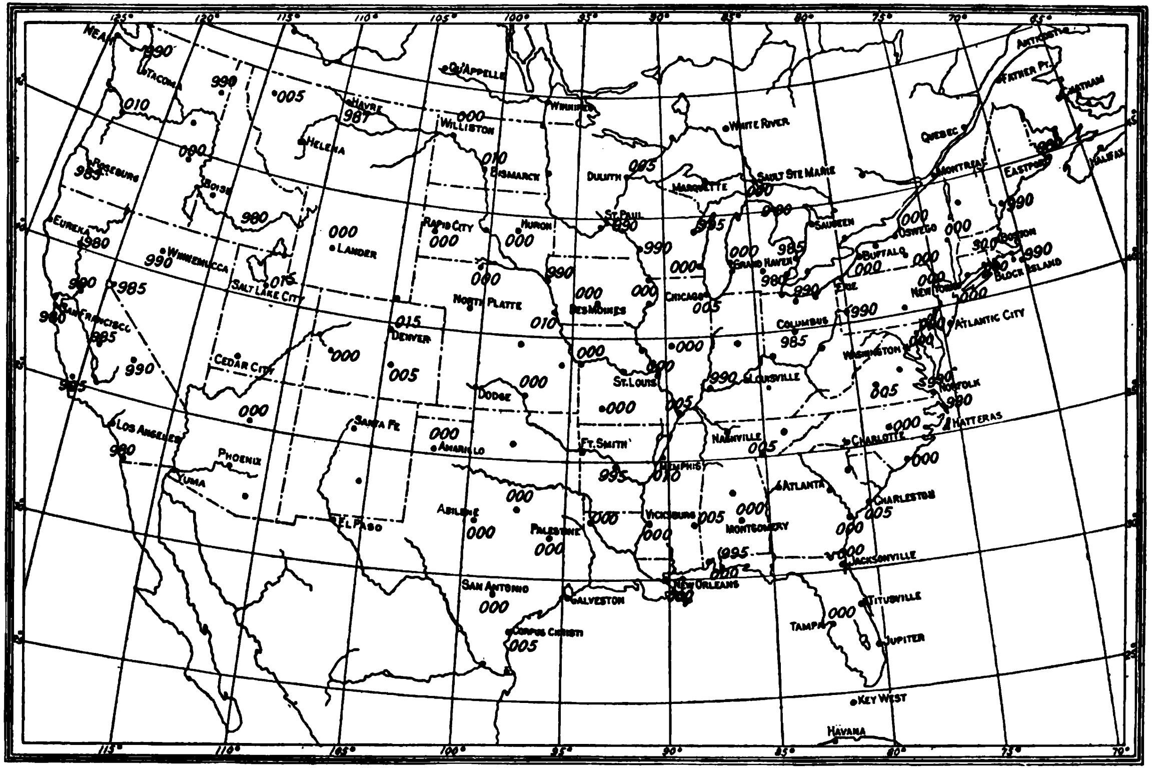
Figures indicate average number of hours clouds were observed before precipitation begins.

CHART XII. BAROMETER HEIGHT PRECEDING PRECIPITATION. AUTUMN.



Figures indicate average number of hours clouds were observed before precipitation begins.

CHART XIII. BAROMETER HEIGHT PRECEDING PRECIPITATION. WINTER.



Figures indicate average number of hours clouds were observed before precipitation begins.

CHART XIV. WIND DIRECTIONS DURING PERIODS OF HIGH TEMPERATURE. SPRING.

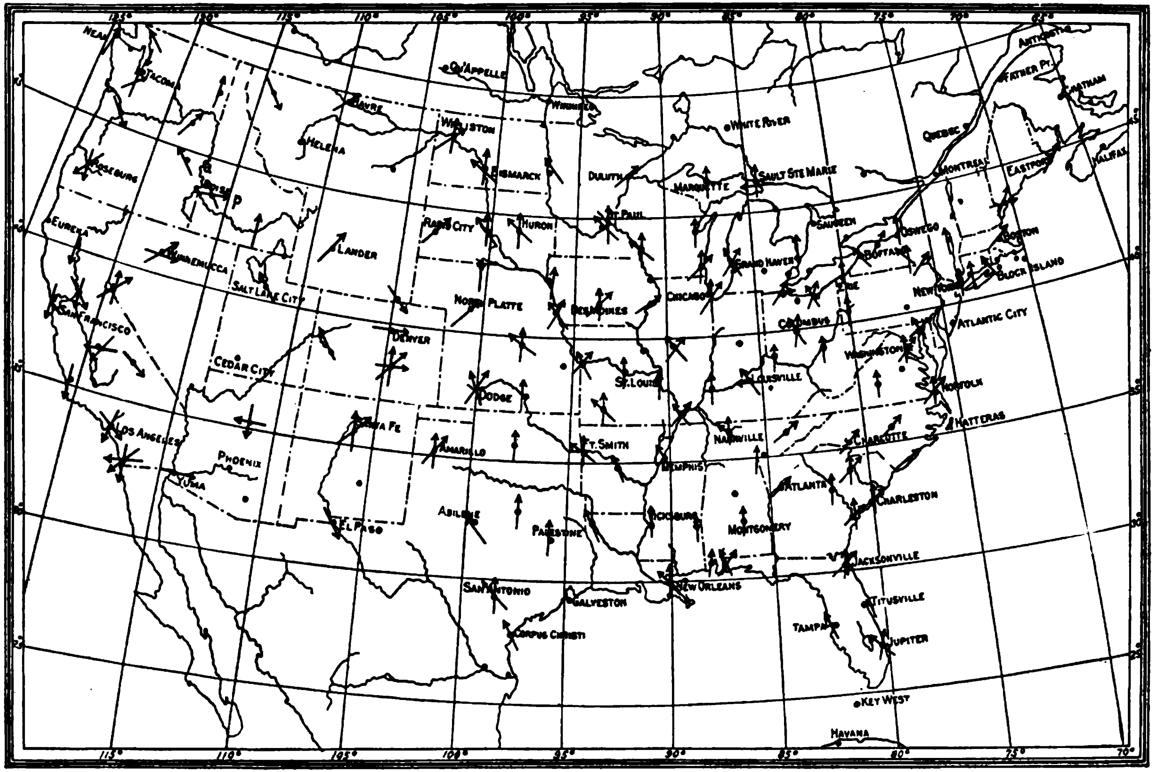


CHART XV. WIND DIRECTIONS DURING PERIODS OF HIGH TEMPERATURE. SUMMER.

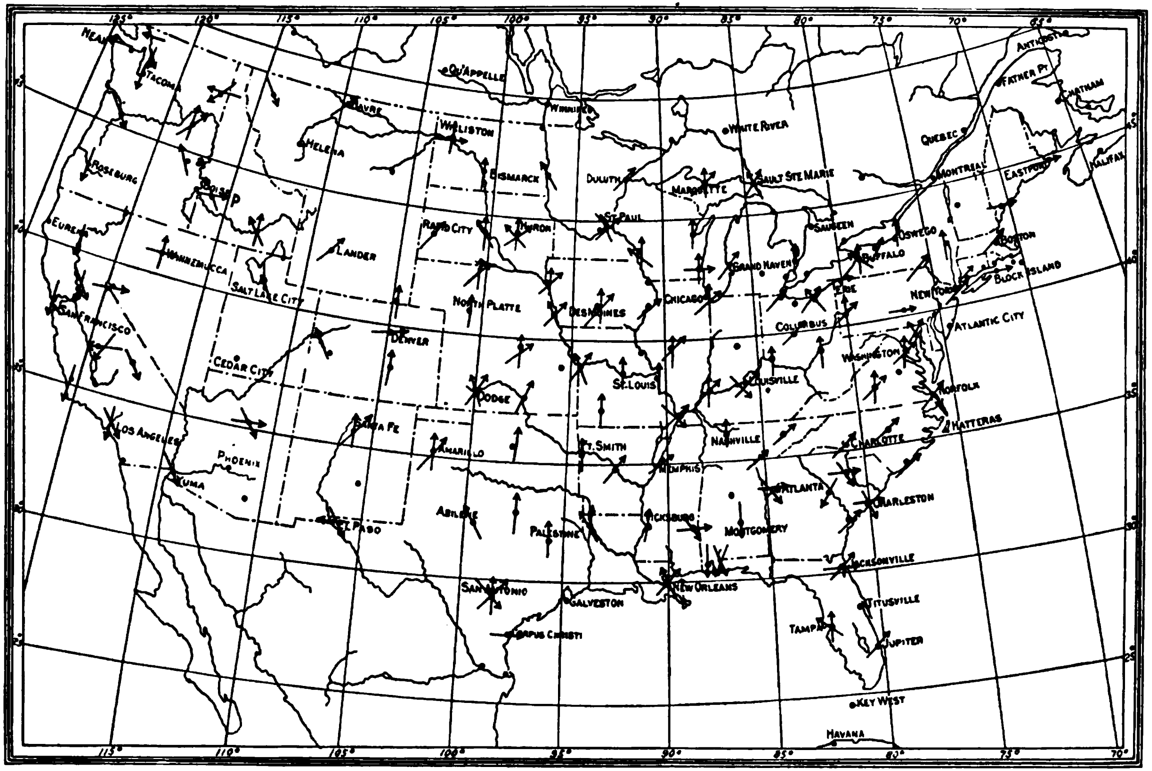


CHART XVI. WIND DIRECTIONS DURING PERIODS OF HIGH TEMPERATURE. AUTUMN.

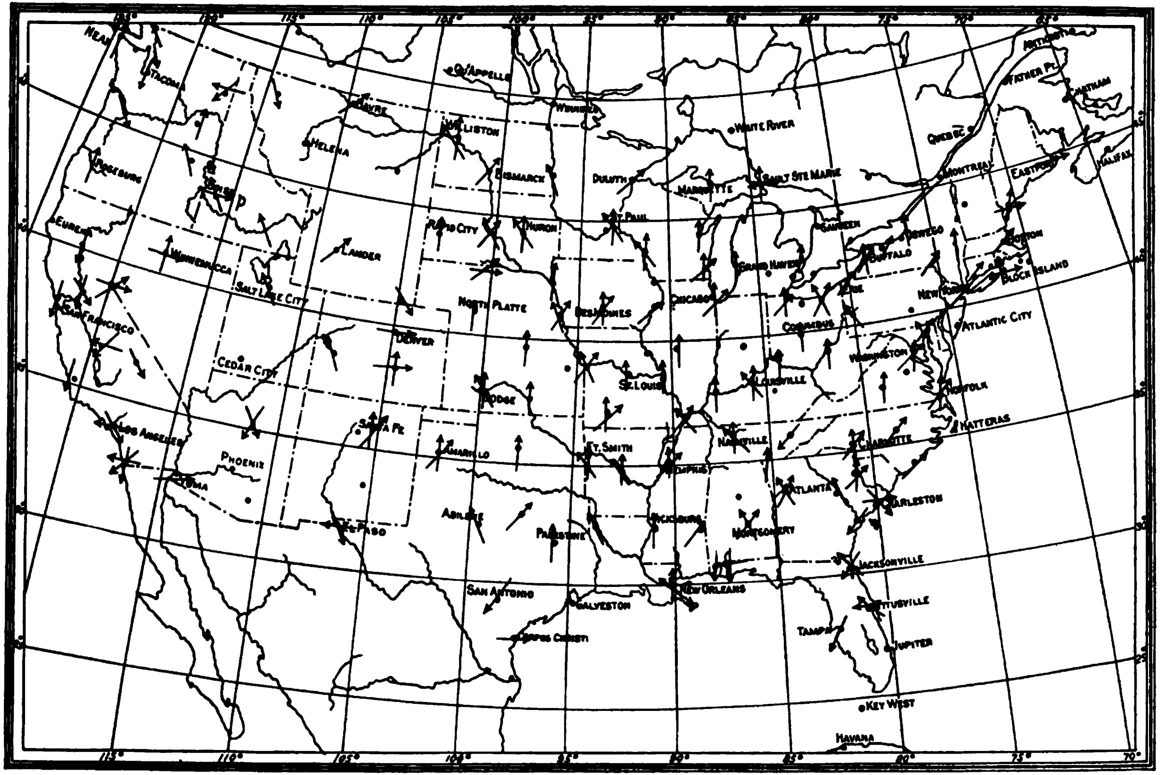


CHART XVII. WIND DIRECTIONS DURING PERIODS OF HIGH TEMPERATURE. WINTER.

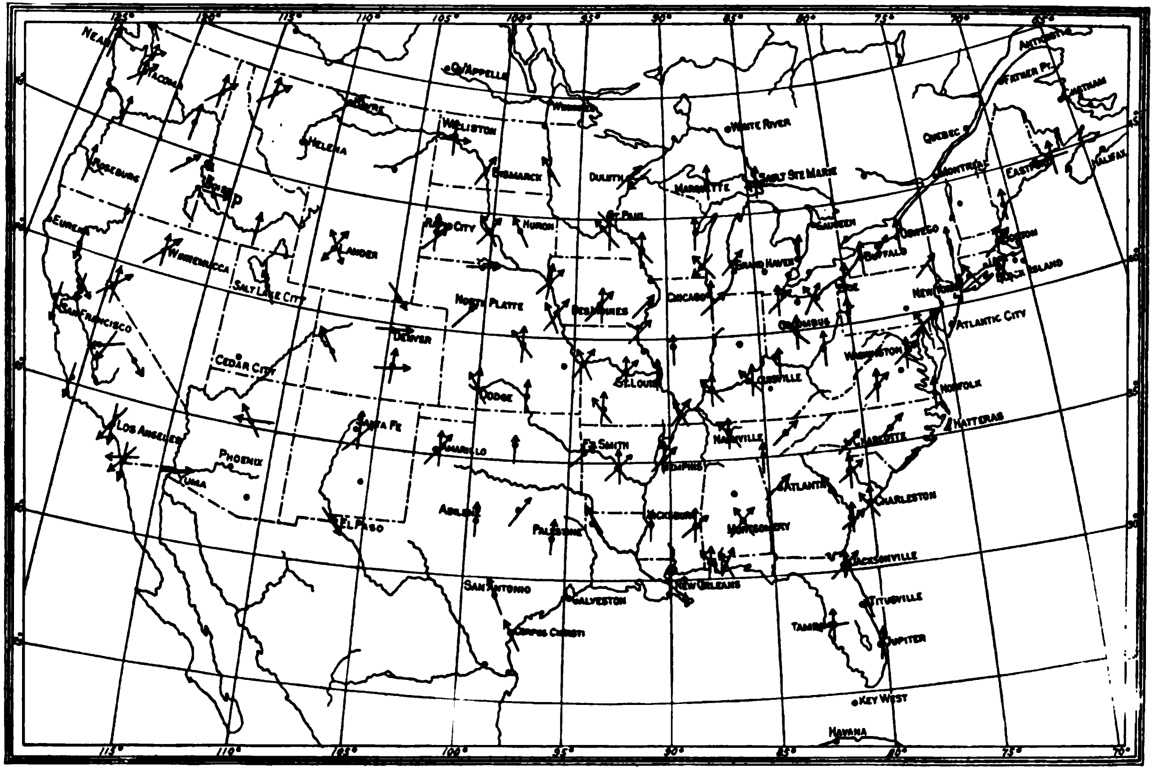


CHART XVIII. WIND DIRECTIONS DURING PERIODS OF LOW TEMPERATURE. SPRING.

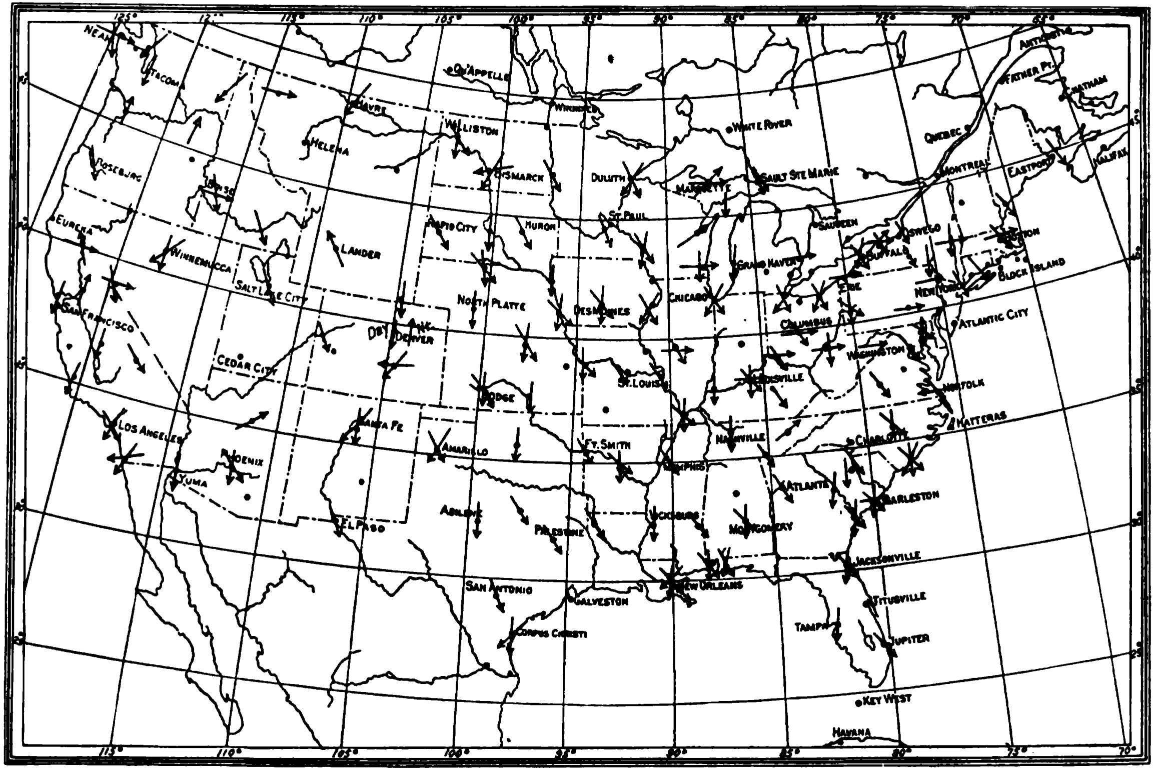


CHART XIX. WIND DIRECTIONS DURING PERIODS OF LOW TEMPERATURE. SUMMER.

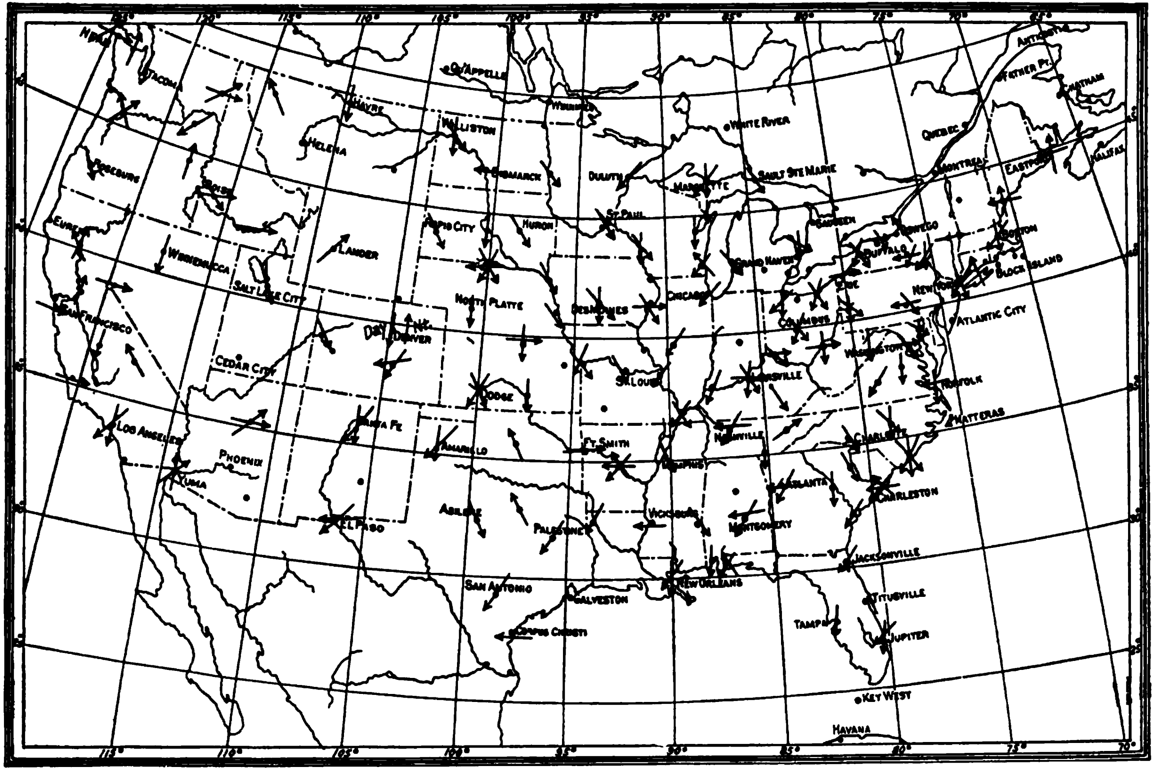


CHART XX. WIND DIRECTIONS DURING PERIODS OF LOW TEMPERATURE. AUTUMN.

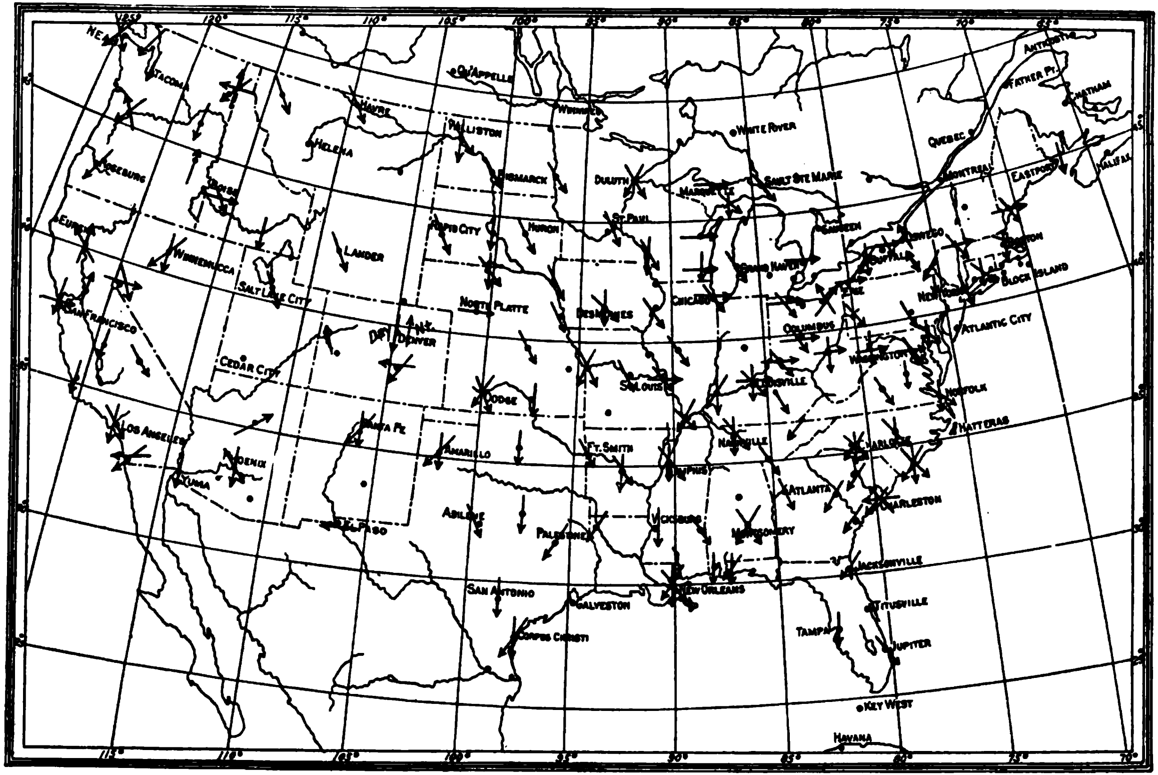
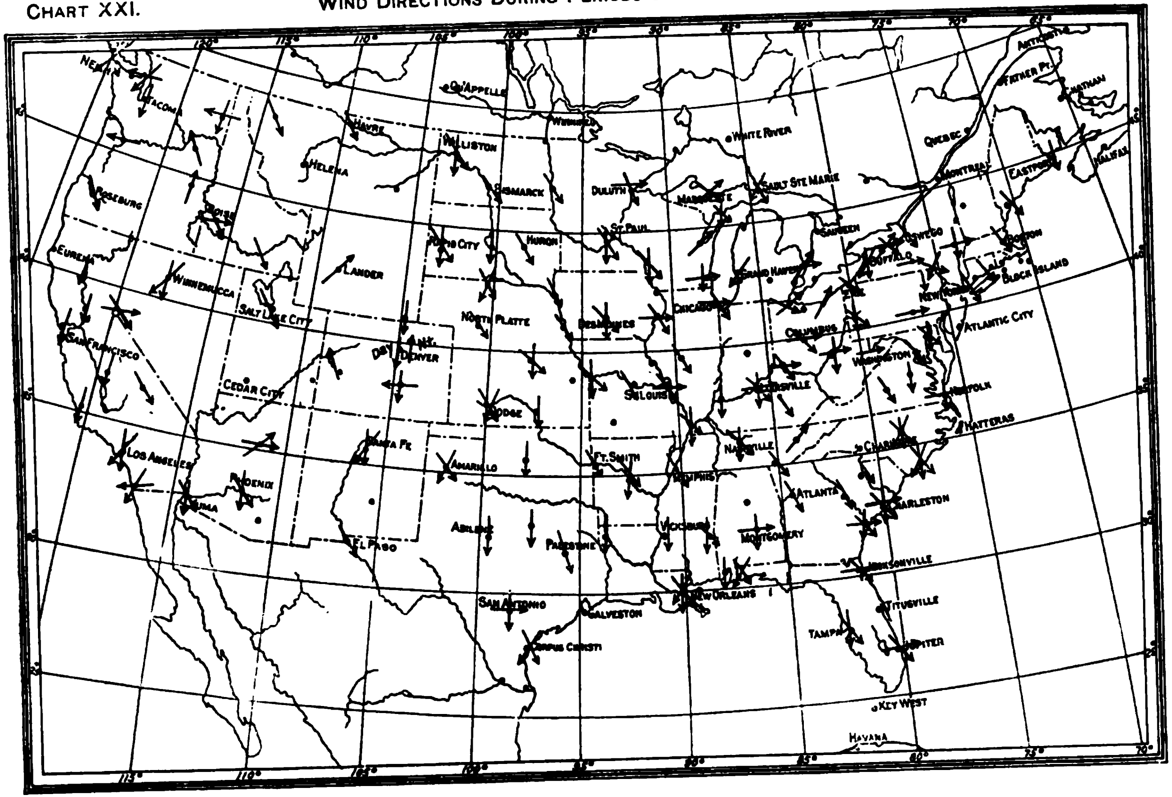


CHART XXI. WIND DIRECTIONS DURING PERIODS OF LOW TEMPERATURE. WINTER.



Bulletin No. 34. W. B. No. 311.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

CLIMATE:

ITS PHYSICAL BASIS AND CONTROLLING FACTORS.

BY

WILLIS L. MOORE,
CHIEF U. S. WEATHER BUREAU.

WASHINGTON:
WEATHER BUREAU.
1904.

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LETTER OF SUBMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., May 11, 1904.

Hon. JAMES WILSON,
Secretary of Agriculture.

SIR: I have the honor to recommend that the inclosed article on Climate, written by me for the Encyclopedia Americana, be printed as a bulletin of the U. S. Department of Agriculture, Weather Bureau. The information contained in the article will doubtless be of value to the younger observers of the service, and to the layman who is not an expert in meteorological science.

Very respectfully, your obedient servant,

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

Approved:
JAMES WILSON,
Secretary.

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CLIMATE.

From the Greek word κλίμα, a slope or inclination. The term was used to denote the effect of the oblique rays of the sun on the temperature of the earth and its atmosphere. To-day it is applied to the sum of the atmospheric conditions as recorded for a long period of time; or, in other words, it is the totality of weather, while "weather" is the physical condition of the atmosphere at a given time, or during a limited period.

One may well speak of the weather to-day, or of last month, of some past year; but not of the climate of a day, a month, or a year. The climate of a place is ascertained by a study of its continuous weather records for a long period of years—the atmospheric pressure, the temperature, the rainfall and snowfall, the time and frequency of frost, the extremes of heat and cold, the direction and velocity of the wind, the amount of air that flows from the different points of the compass, the amount and the intensity of sunshine, the humidity and transparency of the atmosphere, and its electrification.

The study of the causes of the weather and of the laws of storms constitutes that branch of science known as meteorology; climatology is to be considered as a subdivision of meteorology.

Climates may be broadly divided into marine, continental, mountain, and plain, with the many variations produced as these conditions gradually or precipitately shade off the one into the other.

Basis of climate.—If the axis of the earth's rotation were perpendicular to the ecliptic (the plane of its orbit) there would be no seasonal changes, for the rays of the sun would fall upon every point on a parallel of latitude with the same angle of incidence on each day of the year. There would be but one season at any place and it would never end, and there would be little variation in the intensity of storms. But as the axis of the earth is inclined at an angle of 23.5° to the plane of its orbit, and as the direction toward which it points remains nearly constant, there are but two days in each year when both hemispheres (north and south) are exactly one-half in sunshine and one-half in darkness, i. e., at the vernal and autumnal equinoxes, when the sun crosses the equator. At all other times, in each hemisphere, the angle at which the sun's rays strike the earth, the depth of the air through which they pass, the length of the day, and the proportions of each hemisphere immersed in sunlight, are increasing or decreasing. As these four conditions increase in the Northern Hemisphere after the vernal equinox the summer grows upon us, reaching its greatest degree of heat about four weeks after the summer solstice. The lag of temperature is due to the fact that the atmosphere, being heated mainly by radiation from the earth and comparatively little by the direct action of the solar rays, does not attain its greatest heat until after the land and water have reached their maximum temperature and in turn have communicated this heat to the air above. Up to June 21, or the summer solstice, the Northern Hemisphere receives each day more heat than it loses, otherwise it could not gain in temperature; after the solstice the sun each day at meridian is found to have receded a little to the south. At places north of the Tropic of Cancer its rays fall with increasing obliquity and pass through a greater depth of air, and impinge for a less time each day, so that within a few weeks the earth begins to radiate more heat each day than it received. The maximum heat of summer occurs, on the average, when the loss of heat from the earth is just equal to that gained during the day from the sun. This, as previously stated, occurs several weeks after the sun is well on its way southward. About September 21 the autumnal equinox occurs, when the sun crosses the equator, and, as at March 21, the days are of equal length at all latitudes of both hemispheres. On or about December 21—the winter solstice—the sun is farthest south, and the same conditions prevail in the Southern Hemisphere that prevailed in the Northern Hemisphere on June 21. North of the equator the sun is now least effective; its rays reach the earth at the lowest angle through the greatest depth of air, and they are operative for the fewest hours during each day, of any portion of the year, but the greatest cold does not occur. This comes about four weeks later, when the increasing heat received each day by the earth from the sun is just equal to that lost by radiation.

The effect of latitude will be understood by reference to the following figure:

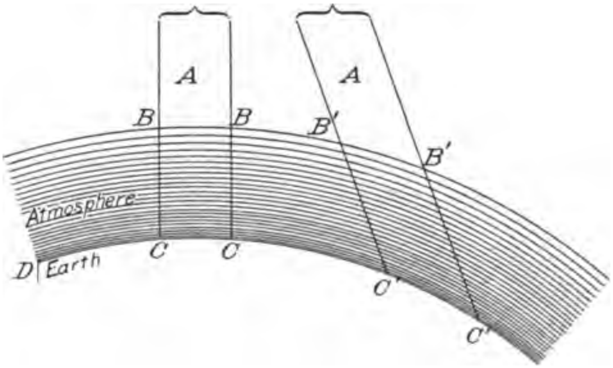

FIG. 1.

As the latitude increases, the rays of the sun will fall with increasing obliquity, and they lose in power by being spread over a larger surface, and by traversing a greater depth of air, which absorbs more of their heat.

The same beam *A*, “when the sun is vertical, is spread over a surface such as *C C*. When the sun is inclined at an angle as shown in the figure, the beam is spread over a surface, *C′ C′*, which is somewhat greater than the first, and it passes through a column of air, *B′ B′ C′ C′*, greater than that of *BBCC*. The intensity of insolation at midday decreases approximately as the cosine of the latitude.”

Near the equator the sun's rays at midday fall perpendicular to the surface of the earth, and there is virtually no change in the length of the day, and consequently there is little variation in the daily or seasonal temperature. As the variation in the length of the day increases with the latitude, there are regions, in the temperate zone, where the length of time that the sun's rays fall upon the earth each day more than compensates for their obliquity. On this account the interior of continents may have at midday a higher temperature than prevails at the equator.

Solar energy is about 7 per cent greater at perihelion (the point in the earth's orbit nearest the sun) than at aphelion (the point farthest away). As perihelion occurs in December, or the summer time of the Southern Hemisphere, and aphelion in its winter, that region has a greater range in the intensity of solar insolation than the Northern Hemisphere. If the land surfaces of the two hemispheres were equal in area, the southern would have colder winters and warmer summers than the northern, and this is the case in portions of the Southern Hemisphere where the land area is large. But the great capacity of water for heat, and the slowness with which it radiates the same, modifies seasonal extremes that otherwise would be much greater.

Variations in climate.—If the earth were all water or all land, and if the land were everywhere of the same elevation, most of the factors that cause variations in climates—often considerable for regions closely contiguous—would be eliminated from the equation. Every point on the same parallel of latitude would have the same mean annual temperature, and the same average heat in summer and the same average cold in winter. New York and London, separated by eleven degrees of latitude, would not, as now, have about the same mean annual temperature. If it were all water, there would be no such extremes of heat and cold as we now know. It is probable that a thermometer exposed in the shade 4 feet from the surface of the earth would not anywhere—even at the equator—ever register above 90° F.; there would be no frost within 35° or 40° of the equator, and zero temperatures would be recorded only in regions within 30° of the poles. If it were all land the heat would be much more intense than now in the Tropics, and in the temperate and frigid zones the heat of summer and the cold of winter would reach extremes unknown at this time.

All the anomalies of climates are caused by the different specific heat capacities of land and water; their different powers of conduction and radiation; the irregular distribution of these two surfaces; the widely-varying elevations of the land; the trend of mountain ranges; the prevailing direction of the winds, and the carrying of large quantities of heat by ocean currents from the equator toward the poles, and the relative quantities of cloud and rain or snow. It is germane to a proper understanding of climate to know something in detail of the manner in which the air is heated. At 100 or 200 miles above the earth's surface there is only the hypothetical ether, which, while too tenuous to be detected or measured by any methods or appliances so far known, is supposed to be the medium that transmits solar energy to the earth and diffuses it through space. This energy, coming in many different wave lengths and with widely-varying intensities of vibration, produces several different phenomena as it is absorbed by or passes through the air, or as it impinges on the surface of the earth. The waves differ in their effects on different objects, depending on the length and the absorptive response of the substances upon which they fall. The waves have heating, lighting, and chemical effects simultaneously in themselves, and it is only the nature of the objects upon which they fall that tends to differentiate them. The atmosphere, even at the surface of the earth, absorbs but a small part of the heat waves. They, therefore, reach the earth and warm its surface; and the earth in turn, by radiation, convection, and conduction, sends back into the air long heat waves, which, unlike the shorter solar waves, are readily absorbed by the atmosphere. The atmosphere is thus warmed from the bottom upward. This accounts for the perpetual freezing temperatures of very high mountain peaks, although they are nearer the sun than are the bases from which they rise. At the height of one mile in free air the temperature is about the same at midday as at midnight. Only during recent years have we begun to realize how extremely thin is the stratum of air next the earth that has sufficient heat for the inception, growth, and maturity of both animal and vegetable life. The raising of the thermometer shelter at the New York City observatory from an elevation of 150 feet above the street to an elevation of 300 feet, has caused an apparent lowering of the mean annual temperature of 2.5° F. On the hottest day in summer, if one could be lifted up to a height of only 1000 feet in free air, he would find a marked change in temperature. The United States Weather Bureau at 16 stations made a total of over 1200 kite observations in the United States in 1897. They showed an average decrease of 7.4° F. for the first 1000 feet of ascent during the warm months, and when the observations were taken near the hour of daily maximum heat the decrease was frequently as much as 15°. At the height of 6 miles the cirrus clouds common to this level are, on account of the low temperature, always composed of minute ice spiculæ, never of watery droplets like the lower cumulus clouds. In the middle latitudes of both hemispheres the air at this height is ceaselessly rushing toward the east, passing uninterruptedly over the cyclonic and anticyclonic systems that cause our storms and cold waves at the surface of the earth. Glaisher and an assistant ascended to a height of about 30,000 feet.

They suffered greatly from the cold, which measured many degrees below zero, although the time of year was September 5. At the height of 6 miles the average temperature, determined by many balloon ascensions is about —60° F.

The difference between continental and marine climates is marked. The same amount of heat will raise the temperature of a land surface four times as high as it will raise that of a water surface. Land is a good absorber and a good radiator, but it is a poor conductor and a poor reflector. The absorbed heat does not penetrate into the ground to any great depth. The land, therefore, retains its absorbed heat near the surface and quickly and freely radiates that which it has absorbed. These conditions give to large land surfaces much higher temperature during the day and much lower temperature during the night than obtain over a water surface of the same latitude and much colder winters and much warmer summers. As an illustration, it may be stated that the Bermuda Islands, in the North Atlantic Ocean, have a mean daily range of temperature of only 10° F., and an annual range of only about 50°; while Memphis, Tenn., near the same latitude, in the interior of a large continent, has a daily range of 17° and an annual range of 112°. At Memphis a temperature of 104° has been recorded in summer and —8° in winter. At Bermuda the temperature generally reaches 90° during the summer, but very rarely exceeds that figure, while temperatures below 45° are also very infrequent. The two places are typical of continental and of marine climates. All regions bordering closely on the sea partake of both climates, the predominating one being determined by the direction in which the coasts trend, their elevation, and the direction and force of the prevailing winds.

In the middle latitudes of both hemispheres the prevailing winds are from the west, and, therefore, continents lying in these regions have a marine climate in their western costal regions, where the air moves from the water to the land, and nearly continental climate in their eastern costal regions, where the general movement of the air is from the land to the sea.

The distance to which moist and equable air conditions extend inland is determined by the elevation of the land and its trend relative to the incident winds and the proximity of mountain ranges. The humid air from the Pacific meets the lofty range that skirts the western shore line of both North and South America; it is forced up the mountain side until the cold of high elevation and the cooling of the air by expansion as it ascends cause it to precipitate its moisture, mostly upon the western side of the mountain, and it passes to the interior of the continent bereft of that life-giving moisture which, were it not for the intervention of the mountains, would spread a mantle of luxuriant vegetation 1000 miles inland. If the disintegrating effects of temperature and rainfall had worn down the Sierras, the Plateau, and the rugged crags of the Rocky Mountains to the height of the Appalachians, the vaporous atmosphere of the Pacific would flow eastward far more freely than now, and meet that which, by the convectional action of cyclones, is frequently carried from the Atlantic Ocean and the Gulf of Mexico inland to the Mississippi Valley; then rain would be more abundant and the whole of the United States would have arable land.

To give a further idea of the effect of mountain systems on the climates of continents one needs only to reverse the conditions just mentioned; if the Appalachian Mountains were as high as the Rocky Mountains, and if they extended farther southward and bordered the Gulf of Mexico, then the Ohio River, the Mississippi, and the Missouri and their many tributaries would not exists, and the world's greatest granary would be a gray and nearly barren plain.

The specific heat of water is greater than that of almost any other substance. It requires 10 times the quantity of heat to raise a pound of water 1° than it does to raise a pound of iron 1°. Solar rays penetrate the sea to a considerable depth; they are quite uniformly absorbed by the stratum penetrated. In consequence of these laws and conditions a vast quantity of heat is stored by the ocean in the Tropics and slowly given to the air as the ocean currents carry the warm water toward the poles. In this connection the writer would correct what he believes to be an exaggerated popular idea relative to the effect of the Gulf Stream on the climate of Europe. The North Atlantic circulation, flowing northward on the western side of the ocean (except a southward current from Davis Strait that chills Labrador and somewhat affects the temperature of the New England coast), and southward along the coast of Europe, is many times more effective in modifying climate than is the Gulf Stream. That the western part of Europe is warmer, more humid, and subject to less radical changes in temperature than equal latitudes in North America, except on the Pacific coast, is due primarily to the great ocean that lies on the west of Europe. Without ocean currents of any description this body of water would give to the air that moves from it to Europe a more equable temperature than is possessed by the eastern part of the North American Continent. Continents, therefore, partake largely of marine climates on their western borders, and principally of continental climates on their eastern borders.

Climate affects the health, happiness, and well-being of people more than any other condition that goes to make up their environment. Within the broad confines of the United States there are many, but not all, shades and varieties of climate. One of the questions most frequently asked is: "Where shall I find a climate possessing both dryness and equability of temperature?" To this interrogatory reply must be made that the ideal climate as regards equability of temperature and absence of moisture does not exist in the United States, but that the nearest approach to it will be found in the great Southwest.

The temperature of the Southwest is not equable in the sense of having an extremely small daily range, but it possesses the quality of annual uniformity in a greater degree than will generally be found elsewhere except on the seacoast, and there the humidity is great.

The most equable temperature on the globe will be found on the high table-lands and plateaus of the Tropics. Santa Fé dé Bogota, in the United States of Colombia, has an average temperature of about 59° F. for all months of the year, and the range for the entire year is less than is often experienced in a single day in some parts of the middle latitudes. But while the ideal temperature may be found on the higher elevations of the Tropics, the rainfall is much greater and more continuous than in this country.

The temperature of a place depends chiefly on three conditions—latitude, elevation, and contiguity to large bodies of water. At sea level in the Tropics extreme conditions of heat and moisture produce very great physical discomfort. But even under the equator it is possible to escape the tropical heat of low levels by ascending from 4000 to 6000 feet. In the economy of nature there is a certain limit beyond which the two extremes, dryness and equability of temperature, can not coexist; thus we may find a region so deficient in moisture as to satisfy the requirements of the case, but the very lack of moisture is a condition that facilitates radiation and thus contributes to great extremes of temperature. Regions may be found, as on the lower Nile, where there is a lack of rainfall coupled with a high and moderately uniform temperature. The mean winter temperature of Cairo, Egypt, is 56° F.; mean summer temperature, 83°; a range from winter to summer of 27°. The mean winter temperature of Phoenix, Ariz., is 52°; mean summer temperature, 87°; a range of 35°. It is by no means difficult to find a counterpart of the far-famed Egyptian climate in the great Southwest.

The dryness of the air and the clearness of the sky are the conditions upon which daily ranges of temperature depend; the greater these, the greater the range of temperature from day to night. While a high summer temperature is characteristic of the Southwest and other portions of the Rocky Mountain Plateau, it is a fact that the sensation of heat as experienced by animal life there is not accurately measured by the ordinary thermometer. The sensation of temperature which we usually refer to the condition of the atmosphere depends not only on the temperature of the air, but also on its dryness and the velocity of the wind. The human organism, when perspiring freely, evaporates the moisture of its surface to the dry air of the interior arid regions, and thus lowers its temperature and prevents sunstroke, which, in the more humid regions from the Mississippi Valley eastward, occur in great number with the air temperature much less than obtains in the West.

The meteorological instrument that registers the temperature of the evaporation, and thus in some measure the actual heat felt by the human body, is the wet-bulb thermometer. The latter, as indicated by its name, is simply an ordinary mercurial thermometer whose bulb is wetted with water at the time of observation.

Effect of climate on the races.—Climate is the most potent of any factor in the environment of races. It is climate and soil, plus heredity and form of government, that produces either vigorous or weak peoples. In this respect it is a question if the United States does not possess a constant potential that, all other conditions being equal, places it in a class by itself.

Climate, soil, and good heredity may produce a race large of statue and of great physical endurance, but unless such a people exist under a liberal form of government, in which public education is fostered and the arts and sciences taught, it is unable to employ its strength in those lucrative vocations that alone give a high per capita of wealth; and wealth means power. It is also weak in defending itself, either in war or in commerce, against a people of less numerical strength that is liberally educated, skilled, and humanely governed.

If one reads of the overthrow of political dynasties and the subversion of trade and commerce, it will occur to him that northmen have usually been conquerors. If we consider the invigorating effect of cold air and marked changes of temperature alone we might expect to find the strongest and most resourceful peoples inside of the Arctic Circle; and if we consider fruitfulness of soil alone we might reasonably expect to find the dominant peoples in the Tropics. But the fact is that the greatest human potentiality occurs somewhere between these two extremes. The boundaries can not be accurately determined by the naming of certain parallels of latitude, but a close approximation is made to the truth in the statement that the most vigorous people physically and the most resourceful mentally will be found in the most northerly regions that will produce not simply cereal crops, but an abundance of them.

The sweep of the cold wave, as it is known in the United States, is quite distinctly North American. Nowhere else on fertile plains, unless it be in Russia, does the temperature show such wide oscillation within such short periods of time, nor do the icy blasts sweep over such a broad area. It is probable that much of the physical and the intellectual energies that have caused the United States to excel in agriculture, in manufacturing, and in commerce, were produced by the invigorating effect of the cold, dry, highly electrified air of the North American cold wave. The anticyclonic systems of air that constitute cold waves have a marked downward component of motion. This motion brings from a considerable altitude to the surface of the earth some of the high electrical potential of the upper air, which is strongly stimulating to man and to other forms of animal life. These cold north winds have a much greater specific gravity than warm and humid winds, and this condition, added to the force with which they come, scatter and diffuse the befouled air near the surface of the earth. Enough has been said to indicate that climate is nearly as important a part of the environment of animal life as it is of the vegetable existence, and that a wide range of annual temperature, if it be not so great as to limit the production of cereal crops, favors the development of strong races of men.

Change of climate.—Notwithstanding the popular notion to the contrary, there is reason to believe that there has been no appreciable change in the climate of any large area within the period covered by authentic history. Changes in the surface of the earth may be noted within the lifetime of an individual, that are thought to prove that a change of climate has taken place, when the alterations may be due to the persistent action of freezing, thawing, rainfall, and flood. Great changes have occurred during geologic periods, but it is the opinion of the writer that they take place so slowly that thousands of years must elapse before their effect is measureable.

Effect of forests on climate.—Extremes of temperature, both heat and cold, are slightly less over forests than over open regions, but the most important effect of forests on climate is the economic conservation of precipitation, diminishing the intensity of floods by restricting the flow-off, and by shading the snow deposited during the winter from the increasing sun of spring and early summer. More moisture is absorbed by the soil when it is covered by forest than when it is cleared of its forest cover, and it follows that deforestation, if extensive, may diminish the supply of springs and streams.

Investigations in Germany and in India seem to indicate that there is an appreciable increase in rainfall as a result of reforestation. In general, forest may be looked upon as the effect rather than the cause of rainfall.

Climate and animals.—The geographic distribution of animals is doubtless the outcome of definite laws—laws that stand in close relation with the past history of the earth through a large portion of geological time. What those laws are forms a subject of great importance in studies of evolution, a subject, it may be remarked, entirely too great to be adequately treated in the present connection. Naturalists are generally of the opinion that all animals have been produced from those that preceded them by some slow process of transmutation or development, and that this modification of animal forms took place very slowly, as evidenced by the fact that the historical period of nearly 4000 years has hardly produced any perceptible change in a single species. That marked changes in the climate of the earth have occurred during the remote past there can be no doubt, and that those changes left a marked impress upon the fauna of the globe there can also be no manner of doubt. The great northern ice sheet and the accompanying cold of the glacial period, if it did not cause the extermination of the receding fauna, doubtles led to its migration to more congenial climates.

The part played in the faunal distribution of the globe by the present climate seems to be indirect rather than direct, although there are many facts which seem to point to a direct relation. While it is true that the fur-bearing animals of the frozen north are generally to be found in arctic regions, yet they send their representatives far into the temperate latitudes, and indeed into the borders of the regions inhabited by the more exclusively tropical species. On the other hand, the tiger, whose home is naturally associated with the hot districts of India and the Indian Archipelago, is equally at home in the elevated regions of the Caucasus and the Himalayas, where his footprints are not infrequently found impressed in fields of snow. Other groups of animals are more limited in their migrations. Some are so closely adapted to an arboreal life that they never stray far beyond the limits of forest vegetation, while others are so tolerant of climatic change that the limit of their possible range is conditioned only by the character and quanity of the food supply and the interposition of impassable physical barriers.

Climate and plants.—The factors necessary to the development of plant life are light, heat, soil, and moisture. The ideal conditions as regards these essentials do not usually obtain, or, if they do, multitudes of plants seek to take possession of the region, so that there is a continuous struggle for existence in which many more plants fail than succeed.

The climatic factors, heat and moisture, are combined in several ways in different parts of the globe, and these combinations give widely different vegetation; thus a maximum of heat and a minimum of water give desert conditions where only specially adapted plants can exist. If, on the other hand, a maximum of heat is combined with a maximum of water, the result will be vegetation such as exists only in the rainy tropics. The possible combinations of the two climatic factors are very numerous, as are also those of soil and the effects of animal life and human agencies. Yet the vegetation of the globe is susceptible of a fairly definite classification. Following Humbolt, and adopting such terms as express in a general manner the vegetation characteristic of each zone, we have the following classification:

Zones of—	Average temperature.
	°
1. Palms and bananas	78–82
2. Tree-ferns and figs	73–78
3. Myrtles and laurels	68–73
4. Evergreens	60–68
5. Deciduous trees	48–60
6. Conifers	40–48
7. Lichens, saxifrages, and dwarf shrubs	32–40
8. Lichens and mosses	32 and below.

While in a general way these zones stretch around the world in wavy belts, somewhat as do the isotherms, similar belts may be found encircling mountain peaks and chains with increasing altitude above sea level. Indeed, it is possible to pass successively from tropic to arctic vegetation on a single mountain peak in the Tropics.

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Bulletin No. 35.—W. B. No. 322.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

LONG-RANGE WEATHER FORECASTS.

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau,

BY

E. B. GARRIOTT,
PROFESSOR OF METEOROLOGY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Weather Bureau,
Washington, D. C., October 28, 1904.

Hon. James Wilson,
Secretary of Agriculture, Washington, D. C.

Sir: I have the honor to transmit herewith a paper on the subject of long-range forecasts, by E. B. Garriott, professor of meteorology, and to recommend its publication as a bulletin of the Weather Bureau. It includes a valuable paper by Prof. C. M. Woodward, of Washington University.

The first chapter, by Professor Garriott, presents a verification of the work of the most prominent of the so-called long-range weather forecasters in the United States that shows conclusively the fallacy of their predictions. The second chapter, by Professor Woodward, shows the impossibility of basing weather predictions on planetary influences. This chapter was published by Professor Woodward in 1875 in Ware's Valley Monthly, and Mr. Tice, whose theory of planetary equinoxes is discussed and refuted, was the predecessor of a long-range weather forecaster who is now operating in St. Louis, Mo.

The remainder of the paper is devoted largely to the discussion of the subject by many of the leading meteorologists of the world. It reviews the literature of long-range weather forecasts, and quotes the opinions of leading scientists regarding the practicability of long-range work. It refers to theories regarding weather periodicities depending upon lunar and planetary influences; summarizes results obtained by comparisons of maximum and minimum sun-spot periods with the phenomena of the earth's atmosphere; states that the next advance in meteorological science must result from extensive research in solar physics and terrestrial magnetism and comparison of solar and terrestrial phenomena; assumes that advances in the period and accuracy of the official weather forecasts depend largely upon a study of atmospheric pressure over great areas, and a determination of the influences that occasion normal and abnormal distribution of the greater atmospheric areas.

The success of the United States Weather Bureau in making conservative forecasts of the weather two or three days in advance has created the hope in the minds of the people that it may be possible to foresee the character of the weather for the coming month or season. All scientific men know that at present it is impossible to gratify this wish, and the Government experts so inform all those who make inquiry. But the mistaken investigator of little knowledge, the pseudo scientist and the astrologer, see their opportunity and at once step into the breach and sell spurious long-range forecasts to a public rendered credulous by the success of the Government scientists. The abuse of the public confidence has become so great that I have thought it justifiable to present to the reader indisputable evidence of the injurious character of monthly or seasonal forecasts.

It is the opinion of the leading meteorologists of the world that public interests are injured by the publication of so-called long-range weather forecasts, especially by such predictions as relate to severe storms, floods, droughts, and other atmospheric disturbances of a dangerous or damaging character. The publication of monthly forecasts has reached such proportions that it is deemed advisable to inform the public as to their harmful character. Some monthly forecasters may be honest, and may, in their ignorance, attach undue importance to storms that accidentally coincide in time of occurrence with certain relative positions of the moon, or with periods of increase or decrease in sun spots, or apparent variations in the solar intensity. To men of this class the occurrence of a storm within the broad area of the United States on or near the day for which they have predicted a storm confirms, in their minds, the value of their system of prediction. They may believe that they have discovered a physical law or a meteorological principle that has not been revealed to astronomers, meteorologists, or any other class of scientific investigators, but the publication of predictions that, by reason of their inaccuracy are positively injurious to agricultural, commercial, and other industrial interests casts a doubt upon the honesty of their makers.

As a result of my personal verification of the work of long-range weather forecasters, some of whom have so far gained the confidence of the rural press as to receive liberal compensation for their prediction, I am led to the conclusion that these forecasters do positive injury to the public at large. It is to be regretted that so many newspapers not only give space to these harmful predictions, but actually pay for them. Forecasts of this description may properly be classed with advertisements of quack medicines—they are both harmful in the extreme.

I hope the time will come when it will be possible to forecast the weather for coming seasons, to specify in what respect the coming month or season will conform to or depart from the weather that is common to the month or season, but that time has not yet arrived, and I believe that we will serve the public interests by teaching the people the limitations of weather forecasting, and by warning them against imposition.

Very respectfully,

WILLIS L. MOORE,
Chief United States Weather Bureau.

Approved.
JAMES WILSON,
Secretary.

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VERIFICATION OF LONG-RANGE WEATHER FORECASTS.

The proof of the forecast is in its verification. Measured by this standard, long-range weather forecasts have an experimental value only, a value that does not justify their employment in the actual work of forecasting for specified dates and places.

Meteorologists who have conceived theories for long-range forecasting, or who have tested theories advanced by others, have applied to the theories the test of facts that are presented by meteorological records, and the results have been negative. Men who issue fake forecasts have adopted an opposite method. They have carefully ignored and concealed facts and have depended upon advertisements of occasional successes that will inevitably occur in any system of chance, and their success may be measured by the extent to which they can impose upon the credulous and the ignorant.

As a rule, it is impossible to subject the rambling and indefinite statements of the long-range weather forecaster to a verification. In the summer of 1903, however, one of these forecasters was induced to submit to the Weather Bureau some forecasts for verification. The forecasts consisted of an enumeration of certain dates around which "storms would cluster and develop great intensity." The periods, or dates, of maximum storm force as forecast and the actual weather conditions that appeared on the dates were as follows:

August 11, 1903.—On this date there were no storms in any part of the United States, and no extraordinary weather conditions were manifested at any point within the region of observation, except that a tropical disturbance of small diameter was apparently moving westward south of Jamaica, West Indies. As the forecast did not specify in what part of the Northern Hemisphere the storms would reach their maximum intensity, it can not be considered that the occurrence of this storm in any way verified the forecast.

August 24, 1903.—On this date no evidence could be discovered of an increase of storm force, the usual stagnant summer conditions prevailing in all parts of the United States.

September 7, 1903.—On this date the weather conditions were not unusual; there were no storms of marked energy in any part of the country. A disturbance covered the northern Rocky Mountain region and the upper Missouri Valley, but it moved northeastward and did not in any way affect the region to the eastward. There was nothing unusual in the disturbance above mentioned. A storm of considerable energy developed in the vicinity of the Bahamas on September 10 and persisted in the vicinity of the Gulf region until the 15th. No mention of this disturbance was made in the forecast.

September 21, 1903.—On this date, likewise, the usual weather conditions prevailed in all parts of the region of observation.

October 6, 1903.—On this date a depression of considerable magnitude covered the eastern slope of the Rocky Mountains. It moved eastward and developed into a severe storm on the Atlantic coast on the 9th and 10th, three days after the date set by the forecaster.

October 19, 1903.—On this date the usual October weather prevailed in all parts of the United States. There was not the slightest evidence of increased storm energy on this date.

This is a plain statement of the weather conditions experienced on the dates when, according to the forecasts, the most severe storms of recent years were to occur. Let us quote of the forecasts:

> Clustering around September 7 and 21, October 5 and 20 will come some of the most severe storms of recent years. These will be so general all around the earth that I advise all to be on guard near the dates named. Storms miss ninety-nine out of one hundred places, but you will at least read of tornadoes, hurricanes, cloud-bursts, electrical storms, seismic disturbances in nearly all sections where these sometimes occur.

Considerable time has already been devoted to an examination of forecasts of this character, and the results thus far obtained show that the forecasters possess no knowledge that would justify them in the making of predictions.

To a long-range forecaster the occurrence of a thunderstorm or an electrical disturbance in some remote corner of the globe during one of his "storm periods" will justify his forecasts.

The matter of verifying the forecasts of this long-range forecaster was again taken up during the present year, the forecasts used being those that appeared in the public press. It was found that one element only was stated in language that would permit a verification—the temperature.

With the approval of the forecaster the forecasts that applied to the region of the ninetieth meridian were alone considered, and these were verified by the records of the Weather Bureau office at Springfield, Ill. The verifications showed that, considering the law of chance, the times when the actual temperature conformed, even in a general way, to the forecasts were surprisingly few. In fact, the forecasts of warm and cold waves, if reversed, would result in a higher percentage of verification.

Forecasts of this character can be of no value to agricultural, commercial, or maritime interests. On the contrary they are misleading, and if given credence are calculated to result in positive injury. Farmers, merchants, and mariners who keep pace with modern progress do not give credence to this class of forecasts. A long-range forecaster who receives remuneration for his work is simply catering to a class of readers who are deficient in a knowledge of the present status of popular science.

There is another long-range weather forecaster who draws his support from the American public who does not depart in any essential manner from the methods employed by the one above referred to. His statements are based upon a consideration of the moon's path with reference to the ecliptic and the equator, the phases of the moon, disturbing causes due to movements and positions of the planets, etc.; in fact, a conglomerate gathering together of all imaginary and obsolete notions regarding weather causes that are calculated to mystify credulous and uninformed people. He predicts the general character of a month with a consciousness that the forecast will be verified in at least some part of a great unspecified area. He then outlines "storm periods," with intervals of two or three days, which are covered by a margin that is claimed for verification purposes, and verifications are claimed if storms occur during the periods or in the intervals in any part of the United States, and, at times, in the Northern Hemisphere. This system of forecasts and verifications admits of no failures. So much for his regular forecasts. Let us now examine some of his special, emphasized predictions:

In the early part of April, 1904, a tornado and severe storms were scheduled in various western papers over the name of this forecaster to appear "right after April 17." The storms failed to materialize in the United States during the period specified. Reports from remote parts of the Northern Hemisphere have not, however, been received, so it is possible that a justification of the forecast will be claimed. Aside from platitudes regarding average weather conditions that prevail in April, he announced that—

> One of the most decided, and perhaps violent, storm periods of the month extends from about the 25th to the 29th.

In the United States the period was a quiet one, and the disturbances that appeared (and one or more surely would appear within the area of the United States during the period specified) were not attended by "very general and violent storms, destructive hailstorms, and abnormal downpours of rain," which, according to the detailed forecast, should have been experienced.

His forecast statement for May, 1904, ends as follows:

> **The fifth storm period will be central on the 29th and there will be violent disturbance. Watch the barometer, and if you have a trembling wife and children clinging to you for protection provide some place of safety in which to resort in case of danger.**

Is it possible to soar to greater heights of nonsense? In what particular continent or country will the storm period be central on the 29th? Is the entire population of the United States, or of the world, expected to dig cellars or caves of shelter in anticipation of a possible occurrence of a tornado whose path of destructive violence would not cover an area represented on a large map by a mark one-half an inch in length made with a sharp pencil? Is it possible that a man who issues such totally unwarranted, sensational, and harmful forecasts is seriously considered by the intelligent portion of the American public? I regret to say that he and others of his kind have a considerable constituency.

THE PLANETARY EQUINOXES—AN EXAMINATION OF MR. TICE'S THEORY.

[By Prof. C. M. Woodward, of Washington University.]

I have been so frequently asked to explain the astronomical grounds on which Mr. Tice's meteorological predictions rest, that I have thought it worth while to put the following explanations, or refutations, on paper. The partial fulfillment of some of his predictions has given them a notoriety which, coupled with the publication of a volume purporting to give a full account of every phenomenon in meteorology, may justify me, or serve as my excuse, in their investigation.

A glance at Mr. John H. Tice's Elements of Meteorology will convince anyone that Mr. Tice is a conscientious, painstaking, and enthusiastic student of meteorology. The record he gives of his labors does not seem to be overstated, and though he is ambitious of a scientific reputation he is not intentionally dishonest or unfair. This much is due at the start to one who has zealously devoted a large part of a long life to scientific subjects. It is, however, with severe disappointment and positive pain that, on a more careful examination of his little work, I discover the author to be lacking in many of the qualifications of a scientific writer. While, therefore, I recognize to the fullest extent his zeal and honesty, it becomes my duty in reviewing the facts and arguments upon which his theory rests to point out grave errors in mathematics and astronomy, and methods of reasoning, to say the least, novel and unsatisfactory. Perhaps, after all, it would be better and kinder to quietly lay Mr. Tice's work on the shelf and say nothing about it. But such a course would be unsatisfactory to all. If the foundations of his theory are well laid, and his conclusions are logically reached, he has certainly made the greatest physical discovery of the century (which is, I think, what he claims), and he richly deserves the strong language of praise and commendation which has greeted his little volume. On the other hand, if Mr. Tice has built upon the sand, and his theory is but a castle of straw which falls under the first blow, it is due to science, and above all it is due to the friends and patrons of Mr. Tice, that the exact truth be told.

It should be premised that astronomers and physicists have during the last half century been carefully observing and tabulating all sorts of phenomena previously considered purely fortuitous. Schwabe's discovery of the regular recurrence of sun-spot periods was the first fruit of such systematic effort. Careful analysis of sun-spot observations since 1826 shows a period of 11.11 years between two successive times of maximum frequency. Next it was found that exactly the same period holds good for special magnetic disturbances or storms, and that the times of maximum and minimum sun-spot frequency agree with the times of maximum and minimum magnetic disturbance. These complete coincidences are what Mr. Tice calls "incontestable facts." Next it was found by observers in the East and West Indies that the years in which the sun spots were the most frequent, and the earth was electrically most excited, were also the years in which hurricanes were the most terrible and most numerous.[b] Various other phenomena seemed to be periodic, agreeing closely with the above.

Such striking coincidences did not fail to suggest a common cause, or, at least, the relation of cause and effect. Jupiter makes a complete revolution in his orbit in 11.86 of our years, a period only slightly larger than that mentioned above. This coincidence and some others affecting the planets have been much discussed, and I can not better show how they have struck the minds of astronomers than by quoting a few words from Mr. Richard A. Proctor's work on The Sun:

> As respects the sequent series of researches by which Messrs. De La Rue, Stewart, and Loewy have endeavored to estimate the influence of the planets upon solar spots, it is to be remarked that the evidence adduced seems as yet not wholly decisive. They believe that it has been rendered probable that Venus exerts a special influence on the solar spots, and that the conjunctions of the planets also affect importantly the condition of the solar photosphere. There is room, in my judgment, for some doubt as to the justice of either conclusion. It should not be forgotten that the planetary system represents so many periodic relations as to render it almost certain that any periodic changes in the sun's condition may be associated statistically with some period of planetary motion—siderial, synodical, nodical, or otherwise. There is a remark toward the close of Carrington's volume on the solar spots which bears very significantly on this subject. After exhibiting the relation between the phenomena of solar spots, as tabulated by Professor Wolf, and Jupiter's variations of distance, he says that "from the year 1870 there is a very fair agreement between the maxima of frequency and maxima of Jupiter's radius vector, and between minima and minima;" but "in the two periods which precede that date

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[[b] Recent studies show no relation between sun spots and hurricanes.—Note by editor.]

there appears to be a total disagreement." "It is important," he then adds, "to see before us an instance in which *eight consecutive cases of general but imperfect agreement between the variation of two physical phenomena are shown to be insufficient to base any conclusions upon*, at the same time that they powerfully stimulate further inquiry with the view of ascertaining whether the discrepancy may admit of future explanation. I would by no means be understood to imply, however, that I regard the conclusions of Messrs. De La Rue, Stewart, and Loewy respecting the influences exerted by the planets on the solar phenomena as inadmissible. On the contrary, I regard them as, on the whole, the most probable yet advanced. Based as they are on observed facts and on statistical relations, they are worthy of the most attentive consideration. They do not seem to me, however, to be by any means *demonstrated*, nor are they so regarded (it is proper to add) by their propounders."

I have quoted fully for two reasons: First, to show that as far as Jupiter is concerned, the main coincidence seems to be between the times of minimum spot frequency and Jupiter's perihelion, and between the times of maximum spot frequency and his aphelion; and, secondly, for the purpose of showing how cautious scientific men are about assuming things to be demonstrated.

Now, of course the most of this was well known to Mr. Tice when he began looking for the "great cycle."[a] He had observed that some phenomena were periodic, and he thought that all might be so, and he hoped by establishing a great meteorological cycle he would have the key for explaining all atmospheric phenomena. So great was his anxiety to secure exact coincidence between the periods I have mentioned, that in spite of some very sensible remarks against the practice of obliterating all individual phenomena by resorting to very general averages, he, according to his own confession, "lumped" the phenomena of sun spots, hurricanes, and magnetic storms with others of less frequency, and succeeded in getting an *average* of 11.83 years. This differs from Jupiter's period but about 0.03 of a year; this he jumped, and adopted Jupiter's period of revolution as the "great cycle." It seems as though this forcing process would be suicidal to any theorizer, for as the period of sun-spot phenomena is beyond all question almost exactly 11.1 years, Mr. Tice's "great cycle" is in excess of that fully three-fourths of a year, an amount which would change exact agreement into total disagreement in five or six periods; and this is just the fate of Mr. Tice's cycle. He seems not to have remembered that finding the average of several unequal periods does not after all make those periods equal.

The point Mr. Tice reaches is that all atmospheric phenomena are produced by planetary equinoxes. (P. 130.) His minor premises are thus stated:

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[a] Although he says: "I *projected* the hypothesis that Jupiter in some unknown way was the cause of the perturbations" (p. 11), I should say here that in all the quotations I make from Professor Tice's book I shall follow his exact language, including punctuation and the use of capitals. The italics, however, will be mine.

> There are two facts that are undeniable; which are not only necessary to establish our theory but they render it incontestable. The first fact is that the Earth and the Atmosphere at the equinoxes always undergo an intense electric disturbance; and the second is that the telluric disturbance extends to and affects the sun, [p. 18] and through it the other planets.

It may be true that the earth undergoes an intense electrical excitement at each equinox. It is generally supposed that with the change of seasons which accompanies the passage of the sun from the north of the equator to the south, or the reverse, the weather is much unsettled. The swinging of the periodic winds, the shifting of the zone of calms, and the high atmospheric tides which must result from the sun's being in the plane of the equator, make this seem quite reasonable and in harmony with observation. But the second "undeniable fact," that the "telluric disturbances extend to and affect the sun," will, I fear, be seriously called in question if it is meant that they *sensibly* affect the sun. In proof of this "fact"—and it is the proof he offers—Mr. Tice says that "it is established by observation that sun spots have a marked maximum during our equinoxes." I do not find this to be true. I have carefully examined the elaborate panoramic plates of Mr. Carrington, in which he gives the solar spots observed by himself during the nine years from 1853 to 1862, *and I find no such maxima in the equinoctial months*, nor, indeed, in any other months. Of course, I am sorry to deny an undeniable fact, especially one so essential to Mr. Tice's argument; but I find no evidence whatever for supposing that the equinoctial storms of our earth sensibly affect the sun.

Having proved the influence of the earth's equinoxes, he wishes to show the immense influence of the equinoxes of Jupiter. Hence the adoption of Jupiter's year as the "great cycle" is all important to his demonstration, and as it is really a point of considerable interest I will ask you to examine carefully this table of dates:

I. Dates of maximum sun-spot frequency.	II. Dates of Jupiter's aphelion.	III. Mr. Tice's major equinoxes of Jupiter.	IV. Mr. Tice's minor equinoxes of Jupiter.
1816.8	1815.20	1812.44	1818.37
1829.5	1827.16	1824.30	1830.23
1837.2	1839.12	1836.16	1842.09
1846.6	1850.98	1848.02	1853.95
1860.2	1862.94	1859.88	1865.81
1871.6	1874.80	1871.74	1877.67

Column I gives the dates of maximum sun-spot frequency in which all observers substantially agree. Column II gives the dates of Jupiter's aphelion. Columns III and IV contain the dates of what Mr. Tice calls the "major" and "minor" equinoxes of Jupiter. As to the determination of these dates I shall have something to say further on.

It is easily seen that neither of the last three columns agrees very closely with the first. This is due, as was said above, to the difference between Jupiter's period and the sun-spot period. The dates in the last three columns regularly increase by 11.86 years, while those in the first are irregular, with an average interval of about eleven years. It is incredible that anyone should consider the coincidence of either one of the last three with the first as "demonstrated." Mr. Tice gives, no doubt unintentionally, a false impression in regard to the dates of sun-spot frequency. He heads Column I of this table "Average maxima," and from his remarks one would conclude that each was the *average* of two dates, agreeing respectively more closely with Columns III and IV. Now, in the first place, the dates in the first column are not averages at all; they are the years when sun spots, magnetic storms, and cyclones were actually most numerous.[a]

An examination of Professor Wolf's analysis of Schwabe's observations shows that Mr. Tice should not have used the heading "*Average maxima.*"

Moreover, the dates of minimum sun-spot frequency are very nearly midway between those of maximum. So that, if Mr. Tice's "major equinox" coincides with the time of the maximum his "minor equinox," instead of being coincident with a second maximum, must nearly coincide with the absolute minimum.

Of course we can not enter more fully into these interesting subjects. Many volumes have been written upon them, and they still claim the attention of astronomers and physicists.[b]

Nothing is clearer than that our author has been guilty of a credulity unbecoming a scientific man in assuming it to be *proved* that Jupiter is the main cause of the solar period, and building upon such a very insecure foundation. He says:

> For ourselves, without any hesitation and qualification, we accept it no longer as a theory, but as demonstrated and verified truth that not only the occurrences of Jupiter's equinoxes but those of the other planets are the causes of the disturbances in the sun, and consequently *in the whole solar system.* (P. 75.)

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[a] When Professor Woodward read this lecture in the hall of Washington University he exhibited a graphical representation of the occurrence of sun spots. The curve of frequency ran sharply to a maximum once during every eleven years like irregular teeth in a saw—EDITOR.

[b] In a recent address Professor Huxley discusses the relation of planets to the sun spots, and while he points out some coincidences in the case of the nearer planets he makes no mention of Jupiter. (See Popular Science Monthly for November, 1875.)

It is worthy of remark in connection with this statement of a firm conviction that Jupiter is the cause of the periodic phenomena of sun spots, that the maximum of spots occurs, according to the table we just examined, when Jupiter is near his aphelion, or greatest distance from the sun. Were he the cause of the spots (of which Mr. Tice has not the slightest doubt) we should expect quite the reverse to be true, as it is not consonant with our experience that a physical cause has the greater effect the farther it is away.

We come now to the most remarkable features of Mr. Tice's book, viz, his theory of planetary equinoxes and his methods of determining their dates. His theory is given above, in his own words. Let us examine his demonstration.

But first I must remind you of a little elementary astronomy. The axes of the sun and the planets preserve almost exactly their directions in space in spite of their revolutions about each other. The different axes are by no means parallel, but each points continuously to the same spot on the infinite celestial sphere. In this statement I ignore the effect of precession and nutation observed in the case of every member of the solar system, because the annual changes are so very small. All are familiar with the fact that the plane of the earth's equator, the "equinoctial," lies half the year on one side the sun and half the year on the other as the earth moves around its orbit, and that twice in the year this plane passes through the sun. At such times the sun appears to us to be on the celestial equator, or "on the line," and as the sun is visible from one pole to the other of the earth just twelve hours by day and invisible just twelve hours by night, these two positions of the earth are called its "equinoxes." A similar statement may be made for each planet. Hence each planet passes two equinoxes during each of its years. When on one side of the sun, say north of it, the planet's south pole is specially exposed to solar influence, and when south of the sun the north pole is similarly exposed. The importance of these changes in producing "seasons" obviously depends upon the size of the angle which the plane of the planet's equator makes with the plane of its path.

But there is another inclined plane which is of first importance in stating Mr. Tice's theory. The sun at the center of the system revolves upon its own axis, and although his axis is nearly perpendicular to the planes of the planets' orbits, it is in no case exactly so. The consequence of this obliquity of the solar axis is that each planet is during one-half of the year exposed to one pole of the sun and during the other half to the other. In the case of the earth, we get our greatest view of the south pole of the sun March 6 and our best view of the north pole September 5. On these dates the earth is at its greatest distances south and north of the plane of the sun's equator. You will observe the degree of coincidence between these dates and those of the equinoxes, March 22 and September 21. The difference, however, is not a constant quantity.[a]

Now, Mr. Tice regards the sun and each one of the planets as an immense magnet, such as would be formed by passing a current of electricity through a coil of wire through the center of which, in a line perpendicular to its plane, there is a bar of soft iron. Of course, such a magnet has a north pole and a south pole, depending upon the direction in which the current flows. He assumes in all his reasonings that this current coincides with the equatorial belt and that the magnetic axis coincides with the axis of rotation. To be sure, he refers to the lack of coincidence of these axes in the case of the earth, and suggests that the like may be true of the sun, but elsewhere he assumes their agreement.[b]

It is obvious that two such magnets would in general influence each other, like poles repelling and unlike poles attracting each other, and in the case of moving magnets that the strength of such influence would vary. Our author thus refers to the earth's alternate exposure to the poles of the sun:

> In consequence of the inclination of the earth's axis to the plane of the Ecliptic, the South magnetic pole of the Sun at one Equinox, and his North magnetic pole at the other, are pointed more directly toward the earth than at any other points on its orbit. (P. 15.)

You will remember that I showed you that the earth was at its points of greatest distance north and south of the sun's equator only about sixteen days before the equinoxes. In the last quotation you will notice that it is assumed that these points coincide. Then he assumes that a like coincidence exists in the case of every planet, and thus proceeds to give the source of the influence of such an equinox.

> These existing causes (which not only arouse the planets to greater activity, *but influence the sun himself* to modify, diversify and vary his energy,) are the equinoxes by which a planet alternately renews its electric vigor; now by the North, and anon by the South magnetic pole of the Sun, thus alternately imbibing electric energies that, we have good reason for believing, differ in many essential properties. (P. 95.)

You will be surprised to know that after making the above statements of the source of the special influence of a planetary equinox, he nowhere mentions the amount of this alternate exposure of a planet to the poles of the sun, except in the case of the earth. He does not seem to know that it is not the same for all planets, and that it has nothing whatever to do with the inclination of the planets' axes to the planes of their orbits. The inclination of the axis alone determines the amount of seasonal changes in a planet, but the amount of change to and from the poles of the sun depends solely on the inclination of the planet's orbit to the plane of the solar equator. Now, astronomers have discovered no law pervading the obliquities of the axes of the various planets. Nothing is known of the direction of the axis of Mercury. Some suppose that the axis of Venus makes an angle of only 15° with the plane of its orbit. The seasonal changes in Mars are slightly greater than in the case of the earth, and the same is true of Saturn, so far as mere obliquity is concerned. In Jupiter seasonal changes are hardly noticeable. It is well known that the case is quite different with the inclination of their orbits to the plane of the sun's equator. This increases as the distance of the several planets from the sun increases. Thus, the inclination of Mercury's orbit is 0° 19′ 51″, and that of Neptune 9° 6′ 51″. The only deviation from actual progression is in the case of the asteroids. From this we see that, in the case of Mercury, variation in exposure to the sun's poles amounts practically to nothing. Should there be a planet interior to Mercury—i. e., should Mr. Tice's Vulcan really exist—it is highly probable that the inclination of its orbit would be less even than that of Mercury. The inclination of Jupiter's orbit is considerable—somewhere near 8°—which I know will delight Mr. Tice, for he evidently overlooked this law and in some confused way has substituted for it the inclination of its axis to its orbit 3°. (See p. 19.)

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[a] Mr. Tice gives the difference between these dates as ten days, but he evidently follows Herschel, who does not give the later and more accurate data.

[b] This suggestion is made by Mr. Tice, in these words:

"Since it is probable that the magnetic poles of the Sun, like those of the Earth, do not coincide with the poles of his axial rotation; hence, if this is the case, each solar pole is equivalent to a moving magnet to all the planets, and therefore a powerful generator of electricity in them" (p. 15). He says (p. 16): "All rotating bodies, from a disc to a sphere, generate electric currents at right angles to the axis of rotation."

From this it is evident that though Mr. Tice's suggestion of a solar magnet is not devoid of interest, he completely fails to follow the idea consistently through.[a]

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[a] It is easy to see that he should have determined when the axes of a planet and the sun were in the same plane, which is the case twice during each orbital revolution. For instance, the axes of the earth and sun are in the same plane July 8 and January 6. At the former date the north poles are most turned toward each other and at the latter the south poles. I must forego any discussion of Mr. Tice's views of physical astronomy. They are vague, inconsistent, and extravagant, and have little to do with meteorology. It will, however, be interesting to cite a few of his observations:

"Electric repulsion and not centrifugal force—as the mechanical theorists suppose—has given the form of oblate spheroids to all planets." (See p. 16.)

"We predict that when science has so far advanced that it can and will observe the phenomena resulting from what are now supposed to be mechanical influences, it will be ascertained that they are *not mechanical but* dynamic, and are produced by electric induction, repulsion, and attraction." (P. 19.)

"The influence exerted by a planet is entirely electric." (P. 13.)

He evidently does not believe in gravitation as a force distinct from electricity, and discards mechanics entirely, for dynamics with Mr. Tice means electricity.

But Mr. Tice endeavors to give us another reason for the potency of a planetary equinox, though it be at the expense of elementary geometry:

> Astronomy establishes two points, namely, that at the equinoxes the Earth's Equator has its greatest obliquity to that of the Sun; and that at or near the solstices it has its least, since the plane of solar rotation then passes through the Earth. Electric laws exact that under such conditions, electric excitement should be at its maximum at the equinoxes and at its minimum at the solstices, and observation has confirmed that the facts correspond with the obvious deductions of Reason. (P. 17.)

This is stated a little differently on page 16:

> Now from the inclination, and from the direction of the inclination of the sun's axis of rotation to the plane of the Ecliptic, and from the inclination of the Earth's axis of rotation to the plane of its orbit, it follows that the plane (equator) of the Sun's rotation, and that of the Earth make their greatest angle with each other at the equinoxes.

Similar statements are made on pages 19 and 72, except that there he does not limit them to the earth, but includes the planets generally, thus assuming that in every case the plane of the sun's equator passes through the planet at its solstices.

Unfortunately astronomy does not establish these two points, and, as far as this count is concerned, "electric laws exact" *nothing whatever.* The deductions of Mr. Tice's reason do not seem to be perfectly "obvious." The simple fact is, as every schoolboy in astronomy knows, the plane of the earth's equator makes with the plane of the sun's equator an *unvarying angle throughout the whole year.* There is positively no maximum and no minimum. This second argument, then, absolutely fails, and his demonstration must rest on the argument (lame as it is) of polar exposure.

I confess I am in great doubt as to what Mr. Tice really means by this second argument. It seems as though he must have deceived himself as to the definition of the angle between the two planes, and that this second reason is only an attempt to restate the first one. On page 72, however, I find them given as two separate reasons. Mr. Tice is either unfortunate in the manner of expressing himself, or in his mathematical training, and either way it is unfortunate for his theory.

Having, as he thinks, established the truth of his electro-equinoctial theory, Mr. Tice is of course anxious to know when these equinoxes actually occur.

> When I was *satisfied* that the equinoxes of Jupiter were the causes of the two marked periods of disturbances in his year, I felt disappointed and discouraged when I found the books silent on this now to me vital point, because it was the turning point—either to disprove or confirm the projected theory. (P. 23.)
>
> Astronomy is silent as to planetary equinoxes; those of the earth excepted. (Ibid.)

Behold how easily the man was satisfied of the truth of his theory of the equinoxes even before he went on his fruitless search for the dates of those puissant epochs. We can not help regretting Mr. Tice's limited opportunities for consulting astronomical data, for the dates of the equinoxes of Mars and Saturn are well known, as are probably those of Jupiter. Great uncertainty attends the data respecting Venus, while nothing is known as to the equinoxes of Mercury, Uranus, and Neptune. (The satellites of the last two suggest the positions of the equatorial planes.) As for Vulcan, as he is chiefly the creation of Mr. Tice's own brain, I shall not deny his right to assign him his equinoxes. What, then, does Mr. Tice do? The quotations already made clearly show the assumption that the equinoxes of a planet occur when it is at its greatest distances north and south of the plane of the solar equator. Consistency demands that he should calculate (as is easily done) when the several planets are at these points and call such positions equinoctial points. Does he do this? Not at all. First, he tried to reason it out in this way, and it carries him in an entirely new direction:

> The first thing was to establish the solsticial points, upon which the books are equally as silent as upon the equinoctial, but as *telluric analogy* had served my purposes well so far, I relied upon it to furnish me both the solsticial and equinoctial points. On the Earth's orbit I found the *perihelion* and *aphelion* points closely coincide with the solsticial points. *I hence inferred that this might be the case with Jupiter;* and if so, that the law might be general. (P. 24.)

In spite of his attempt at reasoning, he tells the exact truth on page 23, when he says:

> We have already stated that we assumed the perihelion and aphelion points of Jupiter's orbit to be intermediate between his equinoctial points.

Let us examine these remarkable statements.

"Telluric analogy" teaches him that the solsticial points of a planet coincide with the perihelion and aphelion points, or, in astronomical language, the line of the equinoxes is at right angles to the lines of apsides. Now, this is certainly intelligible, and, if true, very convenient, but unluckily it is not true either of the planets in general at the present time, nor is it true permanently of any planet, not even of the earth. Had Mr. Tice consulted "telluric analogy" a little more faithfully, he woud have found that owing to the advance of the line of apsides and the retreat of the line of equinoxes, the coincidences between the perihelion and the winter solstice which now exists within eleven days will, in the space of about 5,760 years, become an *exact coincidence between perihelion and the vernal equinox*, and that some 7,000 years ago *perihelion coincided with the autumnal equinox.* Analogy should have taught our author that there is and can be no fixed relations between these points in any case.[a]

Thus far is Mr. Tice furnished with two simple and expeditious, but totally different, methods of "determining" the equinoxes of a planet—

First. They are the points in its orbit farthest removed from the plane of the sun's equator; and

Second. They are the points midway between the perihelion and aphelion points.

But he is not content. A third method, as unlike either of the other two as each is from the truth, is suggested by "telluric analogy."

> By following the suggestion that they (Jupiter's solstices) would be found where the plane of his orbit is highest above, or deepest below the plane of the ecliptic, it was inferred that the Jovian tropics and consequent solstices, might be approximately ascertained. Inquiry was instituted in that direction, and it was ascertained that the Tropics or solstices of Jupiter were at the points inferred, and that they exactly coincided with his perihelion and aphelion; and hence of course his equinoxes must be ninety degrees from either of these points. (P. 24.)

I am almost willing to believe that Mr. Tice never wrote these words, and that they were interpolated by a depraved printer, so profound an ignorance of geometry and astronomy do they betray. I should acquit Mr. Tice of all responsibility in the matter did I not find later another sentence in the same vein.

Thus (p. 26):

> In Jupiter the perihelion and aphelion points on his orbit, and his solsticial points exactly coincide, *judging by the plane of the Ecliptic.*

If this third method means anything, it means that a planet's equinoxes occur at its nodes—i. e., those points on its path where it passes through the ecliptic. His analogy seems to be a little weak, as the earth obstinately refuses to go either "above" or "below" the plane of the ecliptic, and that is the reason, perhaps, that we do not hear of this method again. Of course, these three methods of "determining" the equinoxes of the planets would give very different sets of dates, and there is not the slightest probability that any one of them would chance to be true. The statement quoted above, for instance, that the perihelion and aphelion points of Jupiter's orbit "exactly coincide" with the points of the greatest distance north or south of the ecliptic is false, at the present date, to the amount of nearly two months, and this interval is a quantity varying all the way from nothing to about three years.[a]

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[a] In cosmographical questions a thousand years are as a day. Mr. Tice says (p. 129): "We offer planetary equinoxes for a fundamental principle of meteorology, which are permanently fixed astronomical events that have occurred at their allotted periods as long as the solar system has existed, and will occur as long as it endures." Again, he speaks of calculating when Jupiter "was at either equinox in all time that is past" and "when he will be at all time that is to come." Throughout, Mr. Tice ignores the astronomical fact that no planet has fixed equinoctial points, or, in other words, that in no case is the siderial year the same as the equinoctial year, and that neither of these agrees with the anomalistic year.

As to which of his three methods Mr. Tice does actually use in forming the tables of planetary equinoxes on which his predictions are based, I am not wholly certain. It is clear that in the case of Jupiter he takes the second. In the case of Saturn he discards all three methods and gives very closely the true dates of his equinoxes, thus showing that, in spite of his assertions to the contrary, he found them set down in the books. The date of Saturn's nearest equinox would be, according to Mr. Tice's first method, June 12, 1878; second method, November 11, 1878; third method, December 2, 1872. Mr. Tice gives November 12, 1877. The true date is September 28, 1877.

As to Venus, Mars, and Mercury a brief examination of the table in his appendix convinced me that he had followed neither method carefully.

I admit that it seems incredible that anyone should have mixed up three arbitrary methods of determining the exquinoxes of a planet, as according to my showing Mr. Tice has done. Should anyone doubt the fairness of my report, I beg of him to read our author for himself, but I warn him to take with him a stock of infinite patience, and not to expect to understand the book till he has read it almost literally forward and backward. In extenuation of Mr. Tice's logic I ought to say that I do not think he was conscious of any inconsistency. He was wholly under the spell of his "telluric analogy." The approximate coincidence at the present epoch of the earth's perihelion (January 1), its winter solstice (December 21), and its passing through the sun's equator (December 6) led him to infer that they were equally coincident in the case of the other planets. It would have been very easy for him to see that this was not true in the case of Saturn and only temporarily true of the earth, but he seems to have thought the coincidence incontestably proved by his record of storms. It is fortunate for Mr. Tice that he does not claim absolute accuracy for his equinoctial dates.

> All that I claim is that, they are approximations *arrived at from general principles, the only data at my command.* My purpose is to prove that planetary equinoxes affect, and I might say, determine the meteorological phenomena of our Globe. *I could not succeed in my purpose unless I knew, at least approximately,* the points on the orbits of the several planets where the equinoxes occur. (P. 26.)

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[a] Jupiter was at his greatest distance north of the ecliptic August 29, 1874. He was in aphelion October 24, 1874. Mr. Tice must have "instituted" his inquiry in the direction of a very poor almanac.

If his success is only proportioned to the soundness of his deductions from general principles, there is hardly ground for offering him our congratulations.

Here I must leave Mr. Tice's theory of planetary equinoxes, nor do I propose to discuss his meteorological records, nor say much of his tables of dates. It is certain that the latter have no astronomical value and that by his method of verifying dates one set is as capable of "incontestable proof" as another. As to Mr. Tice's planet Vulcan, on which he relies so largely, I have few words to say. I intimated a moment ago that it was chiefly a creature of Mr. Tice's own brain. Let us see if it is not so.

According to his account, having ascertained that the Saturnian and Jovian equinoxes produce sun spots, earth currents, earthquakes, etc., that the equinoxes of the earth, besides intensifying the effect of the larger planets, were especially fruitful in tropical cyclones, it seems probable to him that all atmospheric phenomena were produced by planetary equinoxes. "Acting on this suggestion" he watched the effect of the equinoxial points of Venus, determined as I have already shown. "The result was astounding, fully verifying the suggestion." "Similar satisfactory and astounding results" attended an observation of the equinoxes of Mercury. But the catalogue of phenomena was not yet exhausted.

> It was soon discovered that not only many phenomena occurred to which it was impossible to assign a place in any of the known cycles, but which under certain conditions, were *so terrifically energetic that they must have a sufficient though unknown cause.*

I dare not venture an opinion as to the meaning of this last clause. He classed all such unaccounted-for phenomena as "unknown." The unknown class consisted chiefly of cyclones, but there were many auroras, some earthquakes, and sun spots. He noted that these phenomena occurred about every twenty-three days. "The suggestion that they might be referable to Vulcan, the gigantic planet nearest the Sun, soon became a firm conviction." Elsewhere (p. 170) he says:

> Other extraordinary phenomena were so far removed from any other known cause, that unless they are due to Vulcan's equinoxes *no other cause can be assigned for them.*

It is obvious, then, that the existence of Vulcan is absolutely necessary to the theory of planetary equinoxes, and the "demonstration" and "verification" of the truth of his "conjecture," that his period of revolution about the sun is forty-six days, is so strong that I almost believe he would have manufactured a new planet out of hand had the suggestion of Vulcan not been already made. To be sure, Mr. Tice says, in an ungarded moment and quite out of keeping with the rest of the book, that his theory may be vulnerable just at this point of Vulcan. This is in the face of the statement that there is no reasonable doubt of the existence of Vulcan, and in spite, too, of his demonstration of the length of his period.

Now, as to the existence of a planet interior to Mercury, astronomers have not been agreed. At one time some had no doubt that one had been seen; at present, however, most astronomers deny that we have any valid ground for believing in the existence of such a planet.

M. Lescarbault, a French physician, and Mr. Lummis, a business man of Manchester, England, and Mr. Tice claim to have seen an interior planet the 1st of March, 1859, and Mr. Lummis, in March, 1862. Neither of these men was an educated astronomer, and neither had an instrument of much power or accuracy. From the rough data furnished by M. Lescarbault, Le Verrier computed the elements of its orbit, making its period nineteen days seventeen hours. From the data furnished by Mr. Lummis two French astronomers computed the elements, one making its period nineteen days twenty-two hours and the other seventeen days thirteen hours. The world knew nothing about Mr. Tice's observation till the publication of his Elements of Meteorology a few months ago.

As to the observation of M. Lescarbault, it ought to be said that at the same hour M. Lais, a French astronomer in Brazil, was examining the surface of the sun, and he—

> is positively certain that nothing of the kind was visible, though the telescope that he employed was considerably more powerful than that of the French physician. (Chambers's Astronomy, p. 50.)

Mr. Tice knew nothing of the observation of Mr. Lummis and the close agreement of the computed periods. He says that as far as his information goes "Vulcan has been seen but twice—once by its discoverer, M. Lescarbault, March 26, 1859," and by himself September 25 or 26 the same year. No one can fail to be struck with the account Mr. Tice gives of his own observation. He says he had the good fortune of seeing Vulcan make a transit a few days after the autumnal equinox in 1859. A few weeks later it occurred to him that it was not Mercury, as at first supposed.

> I then made a record as near as I could of the date, and *its apparent size I recorded as two and one-fourth inches in diameter. As this would give it an enormous size*, I have since got those who also saw it to give me their impression as to its size. I find they vary from mine *a quarter of an inch*, some placing it that much more and others that much less. Probably all these apparent sizes are too great, but they nevertheless clearly establish one thing that the planet is of gigantic dimensions.

You need not be told that such a record as this is totally unscientific and perfectly unintelligible. Apparent size is measured by the visual angle an object subtends and is given in degrees, minutes, and seconds. It is as dependent on the distance as upon actual size. As far as this record goes, the object seen may have been no larger than a football, or it may have equaled the sun. Mr. Tice elsewhere tells us that Vulcan is fully equal to if not much greater than Venus. If now he will be good enough to tell us how he finds that an apparent diameter of 2¼ inches indicates the size of Venus, we will with equal exactness compute Vulcan's distance from us and from the sun, and, by Kepler's third law, its period of revolution. Mr. Tice is singularly unfortunate in the period which he adopts for Vulcan. You will remember that its discovery dates from March 26, 1859, when the Frenchman saw a dark object passing between the earth and the sun, and that Mr. Tice saw it on September 26 the same year. Now, the interval between these two observations was one hundred and eighty-four days. Mr. Tice's Vulcanian period of forty-six days is contained in this exactly four times, so that between the observations Vulcan made four complete revolutions. One can hardly fail to suppose that Mr. Tice was the more willing to adopt forty-six days as his cycle, seeing that it "comes out even." But it is easily seen that either this period is fatal to his observation or his observation is fatal to this period, for during these one hundred and eighty-four days, or six months, the earth had traveled almost exactly one-half of its orbit and Vulcan had made four complete revolutions, his period or year being forty-six days, so that on September 26 Mr. Tice must have been on one side of the sun and Vulcan exactly opposite, as far as possible from a transit. This is a point which Mr. Tice must have innocently overlooked and which it is impossible to explain away or ignore. What Mr. Tice really saw remains to be told.

Mars could be sacrificed with little inconvenience to Mr. Tice's theory; even Mercury could be spared without serious injury; but Vulcan must be preserved at all cost. Vulcan is the very prop that doth sustain the house. His size, his period, and the dates of his equinoxes are all essential to the theory, and yet I have shown you that you must abandon the size of Vulcan (for that depends solely upon Mr. Tice's observation) or you must give up the period of forty-six days. You can take your choice.

There is another fatal objection to Mr. Tice's Vulcan. A period of forty-six days would involve a mean distance from the sun of about 24,000,000 miles; and as Mercury's mean radius is only about 36,000,000, their distance apart when in conjunction would be only about 12,000,000 miles. Now, the least distance between Venus and Mercury is over 30,000,000 miles, so that the strength of Vulcan's attraction for Mercury would be fully six times as great as that of Venus. Le Verrier accounted for the perturbations of Mercury by supposing the mass of Venus to be increased one-tenth. The perturbing force of Mr. Tice's Vulcan would be at least sixty times too great.

Since the suggestion of Vulcan was first made not an eclipse of the sun has been allowed to pass without the appointment of an astronomer in every party of observers whose sole duty has been to search for inter-Mercurial planets while the intense light of the sun should for a moment be darkened. In addition to this the face of the sun has been under almost constant inspection by trained observers at different stations round the earth, each ready to note the transit of a planet, and yet nothing more has been seen of Vulcan during all these sixteen years. The probability that a planet as large as Venus, and as near Mercury as Mr. Tice imagines Vulcan to be, should thus baffle our observers is very small indeed.

Some confusion exists as to the energy of Vulcan's influence at his equinoxes, though I infer that it is immense when immense energy is exhibited and not noticeable when none is noticed; in fact, it depends upon the weather. This cautious inference is based on such remarks as these:

"Vulcan, gigantic in size and fearfully strong in position, with physical laws operating such as our theory postulates, must at his equinoxes produce just such phenomena as the world has witnessed within the last three weeks" (p. 137)—that is, in July last. Vulcan, you will remember, has an equinox every twenty-three days, so that if he "must produce" each time twenty-one days of heavy rain, we shall have forty-two days of rain, or a new deluge, every Vulcanian year.

Again, we find that Vulcan "carved out nine-tenths of the most violent and terrific phenomena of the Jovial, Telluric, and Venusian classes."

On page 137 he says:

> Vulcan's size and position near the sun give him terrific energy, which *he never fails to display at his allotted times.*

And so on with many repetitions.

On the other hand, he says:

> A Vulcanian equinox *ordinarily passes without causing phenomena so remarkable as to attract attention.* (P. 29.)

I will close my remarks upon this branch of the subject by calling your attention to a most remarkable period during which not only Vulcan but nearly all the other planets are shorn of their strength and prowess. On page 50 he says: "There was a period of comparative repose from 1819 to 1829," and this was in spite of a "major equinox" of Jupiter, about 10 equinoxes of Mars, 20 of the earth, 32 of Venus, 40 or 50 of Mercury, and 160 of Vulcan.

I am well aware that even if it has been clearly shown that Mr. Tice's explanations of the influence of a planetary equinox are either weak or altogether false, it will be claimed that such influence may still exist. It is hard to prove a negative, and as no one can deny that even the remotest planet has some influence upon all things terrestrial, an equinoctial disturbance might possibly affect us, just as the falling of an aerolite in China increases the mass of the whole earth, and hence increases the strength of its attraction upon every object on its surface, and this increases the liability of every structure to fall to the ground. This increase is, of course, infinitesimal, but it exists. So with the influence of any planet at any point in its orbit. It is infinitely less than that of the moon even, which was formerly considered the great weather breeder, but which has lately been discarded as wholly insufficient.

I have shown that Mr. Tice's methods of determining the dates of the several equinoxes are confused, contradictory, and incorrect, and yet I can not *prove* that those of Mercury and Venus may not be correct, though the chances are at least a thousand to one against them. Those of Mars, if they were deduced from his perihelion (as I suppose they were), are in error about thirty-four days. Again, although it is not at all probable that any such planet as Mr. Tice's Vulcan exists, he may exist. If he exists, it is highly probable that his orbit lies closely to the plane of the sun's equator, so that Mr. Tice's magnetic theory fails. If he does exist, all the evidences we have fixes his orbital period or year at about nineteen and one-half days instead of forty-six. Now, finally, if Vulcan exists, and his orbit is inclined to the solar equator and his period is forty-six days and he is about the size of Venus, the chances are still twenty-three to one that Mr. Tice has not correctly assumed the dates of his equinoxes, so that the chances on the whole against his all powerful and strictly essential Vulcanian equinoxes are *millions* to *one*. Still, I suppose, we must allow Mr. Tice's enthusiastic followers (and the columns of our newspapers and journals show that he has a fair following) to take that one chance and cling to it so long as they can see truth in his predictions.

I am quite unwilling to make any examination of his meteorological records. Our knowledge of the weather yesterday, last week, or last year is merely local and very imperfect indeed. I have no idea that a day ever passes without great changes in temperature and in atmospheric pressure, without rain or snow, without driving storm or whirlwind, somewhere on the face of the earth. Mr. Tice predicts, for instance, that there will be a heavy storm to-morrow. Do you doubt you will find one if you will only look far enough? Of course, you can prove any prediction of storm if you will only consult a weather bureau in every land and on every sea. And in examining the past, with a terrible equinox every twenty-three days of from seven to eleven days' duration, and five other equinoxes, *each covering half the calendar* (for the duration of each equinox is one-fourth the pho

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vers in Mr. Tice's equinoxes consult the ys, knowing that any physical disturbance to the theory? The sequence of cause and ecessary, and if meteorological phenomena according to Mr. Tice, without astronomical ur again without astronomical cause, and the falls to the ground. I am not going to tell on those few days, for I do not know; but I any one of you suppose, that the face of the devoid of phenomena during that period. e (if you wish to save the theory) no positive her than those invariably connected with day t all a question of degree; it is a question of

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ctually took place during this quiescent interval us impropriety of their doing so and in spite of ey inflicted upon this wonderful theory.

the Weather Review for that month, and I find riginated in the Mississippi Valley and was first n Missouri on the morning of the 13th. It moved th a mean velocity of 50 miles per hour, causing the eastern coast.

and 16th of the month a severe storm prevailed on xtending from central California to the west coast a, and the barometer fell to the unusual reading of rtland, Oreg. At Fort Garry the barometer stood west reading during the month.

he Weather Report of this month Mr. Tice found showed the effect of Vulcan's equinoxes because he hem, but failed to note the greatest phenomenon of planet's period of revolution about the sun), it is certainly easy to account for everything. The only difficult thing to explain is the occasional interval of repose which, in spite of all the planets, we do enjoy. The electrical excitement of the whole earth resulting from the influence of any of the heavenly bodies must be general in its manifestation and not local, so that local storms, from purely astronomical causes, would seem to be impossible. Mr. Tice has spread out each equinox from the necessity he was under of embracing all the phenomena, until pretty nearly every day in every year is covered up, often several times; and were his predictions consistent nearly every day would be consigned to storms.

For example, according to his table the entire year 1875 is under the shadow of a Saturnian equinox; hence one of Farmer Thomas's distributed predictions is always in order: "High wind—and rain—may be expected—about this time." The six months—February, March, April and August, September and October—are embraced by the equinoxes of the earth. From the middle of February to the middle of last July the equinox of Mars raged. Venus adds her influence this year during February and March, June and July, and from the middle of September to the middle of November. Mercury and Vulcan each cover about half of each month throughout the year. The month of October is especially doomed. The combined influence of Saturn, Venus, the earth, Mercury, and Vulcan is expected to produce terriffic results. I have no doubt the prediction will be fully realized. If the valley of the Mississippi chances to escape terrible earthquakes, tornadoes, and floods, it will certainly be found that there was a low barometer in Brazil, or a whirlwind in New Zealand, or an earthquake in Iceland.[a]

Still, on the other hand, there are occasional openings even in Mr. Tice's table where a little quiet freedom from phenomena may be enjoyed. Let us examine January, 1874. That was, according to Mr. Tice, a white month. Jupiter and Saturn, those mighty disturbers of the peace, were quiet. Venus was, after the 6th, reserving her charms for the spring months. The term of service of the warlike Mars did not begin last year till about the 1st of March. Mercury was off duty till the 28th of the month. That terrible blacksmith, Vulcan, with his sledge-hammer blows, was resting idle from the 10th to the 22d of the month, and the weary earth was still dreamlessly sleeping in the arms of her winter solstice. For once all disturbing forces were stilled and throughout the whole solar system peace and tranquillity reigned supreme for the space of twelve days.

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[a] Since the first reading of this paper October has passed. For a Ticean account of the way in which the prediction was verified the reader is referred to the St. Louis Times, October 29.

Nothing ever happens without a cause, and nothing could happen then, *for there was no cause.* Picture to yourself that blissful period. No rain, no snow; no tearing gale, no ominous calm; no low, no high barometer; no low no high thermometer, for all these are phenomena which prove the influence of a planetary equinox.

Dare the faithful believers in Mr. Tice's equinoxes consult the record of those twelve days, knowing that any physical disturbance would be absolutely fatal to the theory? The sequence of cause and effect is invariable and necessary, and if meteorological phenomena occurred then they were, according to Mr. Tice, without astronomical cause, and hence may occur again without astronomical cause, and the whole equinoctial fabric falls to the ground. I am not going to tell you all that did happen on those few days, for I do not know; but I do not suppose, nor does any one of you suppose, that the face of the earth was absolutely devoid of phenomena during that period. Remember there must be (if you wish to save the theory) no positive changes of any kind other than those invariably connected with day and night. It is not at all a question of degree; it is a question of something or nothing.

Now, Mr. Tice quotes from the Weather Review of January, 1874, low barometer No. I on the 3d, 4th, and 5th, and low barometer No. II on the 6th and 7th, as proving the influence of the Vulcanian equinox of the 4th. Again, he quotes the low barometer No. VII of that month, which took place on the 27th and 28th, as indicating the influence of another Vulcanian equinox on the 27th, and seems well satisfied with the verification. But what of the four low barometers, Nos. III, IV, V, and VI, occurring during the middle of the month, each one of which was a storm center traveling across our land?

All these storms actually took place during this quiescent interval in spite of the obvious impropriety of their doing so and in spite of the deadly injury they inflicted upon this wonderful theory.

I have examined the Weather Review for that month, and I find that storm No. IV originated in the Mississippi Valley and was first marked as central in Missouri on the morning of the 13th. It moved to the eastward with a mean velocity of 50 miles per hour, causing very high winds on the eastern coast.

During the 15th and 16th of the month a severe storm prevailed on the Pacific coast, extending from central California to the west coast of British America, and the barometer fell to the unusual reading of 29.06 inches at Portland, Oreg. At Fort Garry the barometer stood at 29 inches, the lowest reading during the month.

In examining the Weather Report of this month Mr. Tice found the storms which showed the effect of Vulcan's equinoxes because he was looking for them, but failed to note the greatest phenomenon of the month because his theory did not require him to examine these uncaused storms.

What took place meanwhile in Europe, Asia, Africa, South America, Australia, and on the oceans stretching to either pole we do not know, nor is information needed, for a single uncaused storm is as much a stumbling block in Mr. Tice's way as though without astronomical cause an earthquake should lay a city in ruins.

It must be remembered that I have not the slightest faith in the accuracy of a single date in Mr. Tice's tables, excepting those of the earth and possibly those of Saturn, and that this test of their value has been made for the purpose of showing how utterly worthless they are to meteorology. Mr. Tice will of course explain the phenomena of January last year by calling to his aid Uranus or Neptune,[a] those planets so inconceivably remote that in comparison Jupiter is a near neighbor, or some other planet still unknown.

Mr. Tice's book contains neither table of contents nor an index, nor does there seem to be any method in its arrangement, but everything is tumbled into its pages in the utmost confusion. There is a new statement of his theory on about every twentieth page, and things are given differently in different places. Throughout the book we find Mr. Tice fighting helplessly and hopelessly against his convictions, so anxious is he not to accept anything as true that is not incontestably proved. On the last page he says: "We have literally and rigidly obeyed the injunction of Locke, 'In science write demonstratively.'" Again: "I love and venerate facts." In commending his theory to the teachers of natural science in our elementary schools he says: "What now passes for Meteorology is less like science than vegetable oysters are like real oysters. *Better teach nothing than teach error.*" (The italics are his.) And yet so overwhelming are the proofs he meets with on all hands that he surrenders without discretion, and we find him repeatedly confessing himself "satisfied" and "convinced" that propositions have been "demonstrated," "verified," and are "irrefragable," whose probability even another would not admit for an instant.

Here I must say adieu to Mr. Tice and his ingenious theory. He leaves the question of meteorology just where he found it—involved in great difficulty and obscurity, but still yielding day by day and inch by inch to the resolute army of students and observers who are besieging it on all sides.

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[a] The awful earthquake of 742 was partly owing to a Saturnian disturbance brought about as usually by an equinox of either Mars, the Earth, or Venus. Mercury may have contributed its influence; Jupiter is ruled out; Vulcan—the "Terrible"—with his sixteen fearful equinoxes, is ignored, but Mr. Tice adds, with charming simplicity and candor, "*besides either Uranus or Neptune may have been at their equinoctial points and thus aided in producing the convulsion.*" (P. 43.) What sublime extravagance is this! It is as though he should pick a few grains of sand on the seashore and say: "These it was which alone turned back the tidal wave!"

In concluding this hasty and imperfect examination I am almost led to apologize for the large demand made upon your time and attention. So baseless have we found our author's theory and so deficient are his arguments that the book seems hardly worthy your serious consideration. My purpose has not been to publish a theory of my own, for I have none, but to help clear the way for the coming of the true science of meteorology which the future certainly has in store for us.

DISCUSSION OF LONG-RANGE WEATHER FORECASTS.

By Professor E. B. **Garriott.**

INTRODUCTION.

Historical references indicate that at an early period in the history of the world man began to associate certain kinds of weather with certain appearances of the heavenly bodies, and that with advances in human knowledge meteorology and astronomy became associated branches of science that embraced all appearances of the sky and the visible phenomena of the atmosphere. In Babylonia rotations of the weather were defined by meteorological and astronomical observations, and in Egypt, where material prosperity has ever rested on the annual rise and fall of the Nile, the periodic appearance of certain constellations revealed the recurring seasons of drought and flood. The Romans and the Greeks were close observers of the weather, and it is a matter of record that during several centuries before Christ they collected and systematized records and traditions regarding the various phenomena of the atmosphere.

Meteorology was not wholly disassociated from astronomy until Copernicus solved the problem of the solar system. The fact was then made clear that the general character of the seasons was controlled by practically immutable astronomical causes, and that the weather forecasts of the ancients were merely statements of climatic or general weather conditions that by observation had been associated with the heavenly constellations. In other words, the system of weather forecasting that had for a basis a calculation of supposed stellar influences was effectually discredited when the sun and the movements of the earth around the sun, and not the stars, were found to be responsible for the weather that is peculiar to the several seasons. An explanation of the apparent success of the system is found in the sharply marked character of seasonal weather in southern Asia and the countries bordering on the Mediterranean Sea, and an additional cause for abandoning the system is found in the fact that as centers of civilization shifted to more northern latitudes the weather of the various seasons exhibited greater irregularities and variations.

In the seventeenth century, the invention of the thermometer, credited to Galileo, and later the invention of the barometer, by Torricelli, afforded means for accurately determining the temperature and weight, or pressure, of the earth's atmosphere, and observations obtained by the use of these instruments facilitated a definition of climatic features and permitted more accurate interpretations of the meaning of local weather signs. During the seventeenth and eighteenth centuries long-range weather forecasting, with other practices of an astrological nature, gradually disappeared from the field of legitimate science. During this period, however, men of recognized scientific attainments were actively engaged in investigations regarding the composition, physical properties, and phenomena of the earth's atmosphere, and climatical problems were systematically considered. Instrumental observations, and especially those furnished by the barometer, aided materially in determining the character of impending weather changes, and barometric indications of the approach and passage of storms were of great value to navigators.

Previous to the nineteenth century man possessed no knowledge of the laws that govern the weather, nor of the mechanical processes that are employed in the production and propagation of storms and other well-marked phenomena of the atmosphere. He had noted, without knowing the reason therefor, that in the Northern Hemisphere northerly winds are usually attended by low temperature and southerly winds by rising temperature; that in the middle latitudes easterly winds are generally followed by rain or snow and westerly winds by clearing or fair weather; that certain cloud formations and movements indicate certain kinds of weather, and that manifestations of atmospheric moisture are of value in determining the character of impending weather changes. He had learned by observation to interpret the meaning of effects produced by certain atmospheric conditions on objects animate and inanimate, and had acquired an intimate knowledge of astronomical events that govern the seasons. About the middle of the eighteenth century Benjamin Franklin, who first conceived the idea that electricity and lightning are identical, discovered that the northeast storms of the Atlantic coast of the United States actually advance from the south or southwest and are first experienced on the southern coasts.

A formal announcement of the law of storms was made by William C. Redfield, of New York, in 1821. Redfield's deductions were based upon observations taken along the Atlantic coast of the United States. He found that the whole of the revolving mass of air that composes the storms of that region advances with a progressive motion from southwest to northeast. In later years he drew conclusions regarding storms in general that have not been materially modified by subsequent research.

The history of meteorological progress during the last half of the nineteenth century is embodied in many reports and publications, reference to which will be made in connection with the subject under discussion. The sum of the achievements of this period in practical and theoretical work and investigation is represented by a rapidly increasing collection of data and facts that afford a sure foundation upon which future work may rest.

The United States Weather Bureau, which possesses facilities that permit it to surpass all other meteorological services in the accuracy of its predictions, now issues forecasts each day for periods of one and two days in advance, and at times the period is extended to three or four days. This is the greatest length of time for which calculations based upon present available data and information can be made. The data referred to is received daily by telegraph from an area that embraces the United States, Canada, the western Atlantic Ocean, the West Indies, and Mexico, and the forecasts are results of careful studies from day to day of atmospheric changes, movements, and developments that appear within the region of observation. The daily calculations thus prepared are subjected to a rigid verification that yields 80 to 85 per cent of verified forecasts that have been made in detail for each twelve hours of the forecast period. In the case of forecasts of severe storms, well-marked cold waves, frosts, and other phases of the weather that are calculated to cause serious loss or inconvenience to commercial and industrial interests, and also in the forecasting of floods in the principal rivers of the country, the forecasts are almost invariably timely and accurate. While the predictions thus issued are not long-range forecasts, it is interesting to note that the period for which forecasts have been officially and regularly made has been extended during the last thirty-three years from eight hours to forty-eight hours without a lowering of percentage of verification.

A further extension of the forecast period depends in a measure on an enlargement of the area covered by telegraphic reports of simultaneous observations. In weather calculations based on recognized physical laws time limitations must be fixed by the period of transition over the region of observation of well-defined storms. If the region has a longitudinal width of 3,000 miles and the average eastward progress of storms is 700 miles a day, the time that will elapse from the first to the last appearance of an average storm within the region of observation will be between four and five days. Allowing the storm one day to enter the region after the first indications of its approach are observed on the western border, and another day for its setting in ahead of the actual center of disturbance, there remains less than three days for forecasts of its advance to the easternmost parts of the region. Assuming that the storm follows the time and route schedule made on its first appearance, it is reasonable to expect that its passage will be followed by two or three days of fine weather, and predictions based on this assumption, while not strictly legitimate, are nevertheless statements of conditions that are natural sequences to the conditions forecast and depend for their verification upon a justification of the original forecast. It appears, therefore, that with present facilities the forecast period can at times be extended to five or six days. In view of this statement, and with a due consideration of the necessarily slow advances that are usually made in the arts and sciences, the progress of weather forecasting during the last third of a century has been remarkable, and another quarter of a century will undoubtedly show a corresponding advance. In the meantime data, knowledge, experience, and honest, well-directed effort will be persistently applied to the problem of practical meteorology in the belief that the particular laws of nature that may control rotations of the weather will be determined.

THE BASIS OF LONG-RANGE FORECASTS.

"Planetary meteorology" is the term applied to the practice of the more prominent long-range forecasters, and planetary meteorology is one of the relics of astrology; fortune telling is another. When advances in astronomical knowledge made clear to the world at large that the fixed stars do not exercise an influence upon the weather, exponents of the weather branch of the ancient art of astrology with one accord placed upon the moon and several of the planets of the solar system the responsibility of regular and irregular forms of weather. To the moon, however, was given the burden of the responsibility, for be it known that centuries before the Christian era the periods of the new and full moon were associated with current weather, and rotations of certain weather types were supposed to attend a nineteen-year lunar cycle, during which the new and the full moons are repeated on corresponding days of the month.

Some of the most financially successful long-range forecasters of the present time base their forecasts on the moon's path with reference to the ecliptic and the earth's equator, and strengthen their statements by allusions to mysterious Vulcan, eclipses, occultations, and quotations from the Scriptures. Others employ the nineteen-year moon cycle and fall back upon a fund of mysteriously acquired superhuman wisdom and, incidentally, upon past records of the weather; and the manipulation of past records, which have a positive value in climatic work, represents their stock in trade. Other prophets appear from time to time and, lacking in "business" faculty, quickly disappear.

A careful consideration of the merits of the moon as a controller of the weather presents a number of reasons why the claims of fair Cynthia's disciples should be given respectful consideration. The belief is entirely plausible that the earth's nearest neighbor should assume a part in the management of her affairs. The moon's aspect is changing every day, and so is the weather. The phases of the moon change once a week, and we have a storm about once a week. The storms may be either "regular" or "reactionary;" that is, we may get them coming or going, either before or after the change in the moon. Then there is a certain sentimental feeling for the moon that is due to an inherent regard in the human breast for the mystical and the mysterious. And, finally, the formidable interrogation is launched against unbelievers: The moon influences the tides of the oceans, why should it not influence the weather?

With the burden of proof thus placed upon the scientist, who demands corroborating facts before he can accept in all faith unsupported assumptions of superior wisdom, the long-range weather forecaster continues to exercise, for a consideration drawn from the gentle public, the time-honored practice of playing upon the fancy of the credulous.

OPINIONS REGARDING THE INFLUENCE OF THE MOON ON THE WEATHER.

The principal object of this paper is to present a summary of the quoted opinions of prominent meteorologists who have endeavored to justify the practice of long-range weather forecasts by facts or theoretical deductions based on known physical laws. A consensus of the opinion of meteorologists appears to be that while the moon undoubtedly exerts a certain influence on the earth's atmosphere the influences are not directly and noticeably contributary to marked normal or abnormal weather conditions.

In a letter delivered by Prof. Dr. J. M. Pernter to the Association for the advancement of Scientific Knowledge, Vienna, January 14, 1903, the following remarks were made regarding the moon as a weather forecasting medium:

> The moon is credited with being the principal dominator of the changes of the weather. The weather is supposed to change by preference with the moon; therefore the new moon and the full moon especially possess the power of influencing the weather, and one of the most widely spread weather rules is that the weather changes with the new moon and with the full moon. However, by many others the first and last quarters are considered of greatest importance. Especially clever observers of the influence of the moon upon the weather pretend to have also observed the distinctive individual influences of the phases known as octants. In general the opinion is very widespread that the decreasing moon exercises a weak and the increasing moon a strong influence. Thus far the theory of the influence of the moon on the weather is the direct result of the popular belief in the moon, without regard to any scientific basis.

Rev. F. L. Odenbach, director of the meteorological observatory, St. Ignatius College, Cleveland, Ohio, has written as follows (Monthly Weather Review, June, 1903):

> With reference to the rain theory of Mr. H. C. Russell, of Sydney, New South Wales, I have looked up the extensive literature on the subject extending through

the two last centuries up to date. An immense amount has been written on the subject.

The sum and substance of all the work done along this line has failed to bring out anything that might be considered a law or be used as a safe rule in questions of climatology or weather forecasting.

I myself think that the moon (and why not the sun and the planets?) *must* have some influence on our weather. Yet this influence must be so slight or so concealed that all these years of observation and hard work have not resulted in anything worth considering.

The great objection I have to this new exposition of Mr. Russell is that from the start he distinguishes between the rainfall on the coast and that of the interior. Why? In this point Mr. Russell follows all of his predecessors. The rule is bolstered up with exceptions and conditions, subconditions, and special combinations until the application becomes a mere guesswork. My general impression on the subject is that about as much time has been wasted on this matter as on the "Perpetuum mobile" and with about the same success. Being in this mood I think it best not to write anything for the Review for fear lest some might take up the matter and neglect other lines of much more importance and far greater utility.

The rain theory of Mr. H. C. Russell, referred to, is discussed as follows by Prof. Cleveland Abbe in the Monthly Weather Review for November, 1902:

Mr. H. C. Russell, director of the observatory at Sydney, New South Wales, has published in the Journal and Proceedings of the Royal Society of New South Wales, for the year 1901, a memoir on the relation of the moon's motion in declination and the quantity of rain in that colony, in which the author concludes "that rain is clearly shown to come in abundance when the moon is in certain degrees of her motion south; but when the moon begins to go north then droughty conditions prevail for seven or even eight years. This phenomenon repeated for three periods of nineteen years each constitutes a marvelous coincidence such that there must be a law connecting the two phenomena.

The influence of the moon on the weather is a matter that will not be downed by the exercise of any amount of common sense. According to the most ancient notions, the moon ought to have and must have a controlling influence in excess of the sun's, and everyone who seeks to demonstrate its power is liable to become infatuated with the study. The moon has so many variations north and south of the equator, north and south of the ecliptic, to and from the earth, from new moon to full moon, conspiring with the sun and opposing the sun, that it does seem as though one ought to be able to make its periodical oscillations agree with some of the many variations in the aspect of the weather. However, we know of but one relation between the moon and the earth's atmosphere that can be said to have been settled upon a rational basis, and that is the matter of atmospheric tides. Laplace stated that the semidiurnal lunar tide in the atmosphere ought to amount to about 0.003 inch of barometric pressure for equatorial stations, and this agrees with the results of observations carried on at Batavia, Java. His formulæ also showed, although we believe he did not state the fact, that as the moon moves north and south of the equator monthly, there ought to be a fortnightly tide, or a general pull of the atmosphere southward for two weeks and northward for two weeks. This we believe was first demonstrated as an observable quantity by A. Poincaré, a civil engineer of Paris, and a member of the Meteorological Society of France. From his articles published by that society in 1885–1888 we learn that the average barometric pressure on parallels of latitude around the whole globe, as measured by the international maps published by the United States Weather Bureau, gives the folowing results: The pressure on latitude 40° minus that on latitude 10° is $+1.88$ millimeters when the moon is in the extreme south and $+4.82$ millimeters when the moon is in the extreme north. The normal difference is $+3.35$. This indicates that when the moon is farther north there is a slight accumulation of atmosphere in the Northern Hemisphere amounting to 1.47 millimeters, or 0.06 inch of pressure on the parallel of 40°.

Now, all lunar phenomena go through rather rapid periodic changes. What happens in one part of the lunar month is offset by an opposite effect in the other half of the month, or what happens when the sun and moon conspire is offset by an opposite effect a few months or years later, when the sun and moon oppose each other. When the moon is far south and begins to go north, according to Mr. Russell, droughty conditions prevail and continue for seven or eight years. But the strange part is that the moon begins to go north from her extreme southern position every month without exception, not only just before the seven or eight year drought, but during the whole of that long period, and continues to do so during the whole of the succeeding rainy period. How can her beginning to go north be rationally supposed to be a basis for predicting droughts in one case and rains in another?

But if we lay aside these vagaries about the moon and recognize Mr. Russell's meteorological induction that droughty conditions do prevail for seven or eight years in Australia, followed by years of rain, and that this cycle of droughts and rains has been repeated about three times since 1840, then we have a fair observational basis upon which to build a rational explanation. Now, this periodicity, or rather the irregular succession of good seasons and bad seasons, is a fact recognized in every portion of the world. We also have enough data to show that in most cases a drought in one portion of the globe is accompanied by rains in other portions, and that the regions of excess and deficiency of rain move over the surface of the globe month by month and year by year. They do not move in courses so nearly parallel as to justify long-range predictions any more than do our storm centers, but the movements are certainly governed by laws, and we can begin to generalize as a first step in the process from induction to deduction.

For instance, floods in the upper Nile, due to rains in the highlands of central Africa, mean that an unusual proportion of moisture has been taken from the southeast trade-wind current, and that, therefore, when that has been turned northeastward over the Indian Ocean and has become the southwest monsoon of India, it will bring droughts over the western portion of that country. A drought in New South Wales or on the southeast side of Australia means a deficiency in the eastern winds blowing on that coast, and especially so in the rainy season, or December, January, February, and March. But this means that the great area of high pressure over the Indian Ocean at latitude 30° south has been pushed farther west than usual, or, in other words, that the general circulation of the atmosphere in that region has been disturbed. Now, such a disturbance, continuing over several months or even years, can hardly be produced by the rapidly changing moon; it might be due to secular changes in the quantity and quality of the solar heat, but is most of all likely to be simply the result of accumulations of pressure, temperature, and moisture in various portions of the earth's atmosphere. Australia has about the same area as the United States, but lies on the average about 15° nearer the equator. This latter feature gives it soil temperatures and monsoon influences similar to those that prevail in northern Africa, so that it may itself produce an appreciable disturbance of the general circulation in the southern half of our atmosphere. But the principal cause of the droughts in Australia and India is undoubtedly to be found in the changes going on periodically in the relation between the general atmospheric pressure and resultant circulation in the south and in the north, or between Cape Colony and Australia, China, and eastern Siberia. In this large portion of the globe a system of circulation prevails that is affected but comparatively little by what goes on to the west of it and to the north of it. A large quantity of air enters into this region from the Antarctic Ocean and passes out of it as the southwest monsoon of southern Asia to eventually become the westerly winds of the North Pacific. We may, therefore, look for some connection by this roundabout way between the droughts and rains of Australia or southeastern Asia and those of northwestern America.

It may be interesting at this point to quote two brief utterances regarding the effect on the weather of lunar influences that reflect the attitude of the scientific world toward this matter in 1868 and thirty-five years later. The first was made by Alexander Buchan, M. A., secretary of the Scottish Meteorological Society, and was, in part, as follows:

> It is an opinion that has been long and popularly entertained that the changes of the moon have so great an influence on the weather that they may be employed with considerable confidence in prediction. That the moon's changes exercise an influence so strongly marked as to make itself almost immediately felt in bringing about fair or rainy or settled or stormy weather, an examination of meteorological records, extending over many years, conclusively disproves.

The following remarks by Prof. Alfred Angot, of the Central Meteorological Bureau, in Paris, that appear in the Monthly Weather Review for July, 1901, will conclude the presentation of direct testimony concerning lunar influences on meteorology In a final summary of the general subject of long-range forecasts, however, further comment will appear regarding the alleged domination by the moon of terrestrial weather:

> The idea that the moon exerts any influence on meteorological phenomena goes back to the most ancient times; there is no belief that has left more traces in the popular traditions in regard to the weather, nor that has been the subject of more controversy.
>
> Let us recall that the time occupied by a true or sideral revolution of the moon is 27d. 7h. 43m., or 27.322 days; the apparent or synodic period, after which the sun, earth, and moon return to their same respective positions, is a little longer, viz. 29d. 12h. 44m., or 29.531 days. It is after this latter interval that the *phases* of the moon again become the same. The *anomalous revolution* or mean value of the intervals of time separating two consecutive passages of the moon through its shortest distance from the earth is 27d. 13h. 19m., or 27.555 days. Finally, the orbit of the moon has a mean inclination to the ecliptic of 5° 8′ 48″; the maximum declination of the moon therefore varies between 18° 10′ and 28° 45′, while the maximum declination of the sun is 28° 27′.
>
> The moon imparts to us only a very small proportion of the light and heat that she receives from the sun. The heat that she sends toward the earth is so feeble that the most powerful instruments and the most delicate methods of measurement must be employed to discover it; there can, therefore, not be any question of a luminous action of the moon and much less of a caloric action,

and we can scarcely think of anything else but an attraction analogous to that produced by the tides on the great masses of water of the oceans. It is therefore necessary to first seek to discover whether the action of the moon does produce atmospheric tides that show themselves by the periodic variations in the height of the barometer.

If we observe the pressure at the lunar hours, that is to say, when the moon passes the meridian and she is distant from it 15°, 30°, 45°, etc., and if we take hourly means of the values observed during a very long period of time, in order to eliminate the disturbances, these means will certainly give an indication of a lunar tide, but extremely feeble; it will only be found at the equatorial stations and disappears entirely in the middle latitudes. At Batavia the maximum pressure occurs a half hour or an hour after the upper and lower passages of the moon over the meridian; the minimum occurs from six to seven lunar hours after the maximum; the total extent of the variation is only 0.11 millimeter, which corresponds to a column of water of about 1.5 millimeter (or one seven-thousandth part of the standard average atmospheric pressure.—Ed.).

The insignificance of the diurnal lunar variation of pressure indicates that this must also be true of the variation corresponding to the revolution of the moon around the earth; that is to say, to the phases of the moon. In Batavia the pressure is the feeblest at the time of the new moon and most powerful shortly after the period of full moon. The total extent of this oscillation does not reach 0.2 millimeter. The diurnal rotation and the synodic revolution of the moon therefore cause tides in the atmosphere as well as in the oceans, but the atmospheric tides are so extremely feeble that they scarcely exceed the limit of accuracy of the barometric observations.

The study of the influence of the synodic revolution or of the phases of the moon upon other meteorological phenomena produces results which are absolutely contradictory, and which have been discussed in detail by Arago and more recently by Van Bebber. We shall therefore limit ourselves to summarizing briefly the conclusions arrived at by them.

The temperature, the cloudiness, and storms do not show any periodicity in relation to that of the phases of the moon. In Germany north and northeast winds seem most frequent in the period of the last quarter of the moon and most rare in the first quarter; the southwest winds show an inverse variation. But this law has not been verified in any other countries.

At Paris and in Germany the maximum number of rainy days occurs between the first quarter and the full moon; the minimum number between the last quarter and the new moon. The relation of the maximum to the minimum is 1.26 at Paris and 1.21 in Germany. It would, therefore, at first sight seem that there is here a true law and that the prospects for rain are greater by a fourth or a fifth after the first quarter than after the last; but even this would be too slight a difference to be made use of for a serious forecast. Besides, this law does not hold good for the south of France. At Orange, for example, the minimum of days with rain occurs between the full moon and the last quarter and at Montpelier in the first quarter. If there is any relation between the phases of the moon and the rainfall, this relation is, therefore, very complex and variable from one region to another.

The study of the changes of the weather has produced still less convincing results. In discussing the observations made at Padua in the last century, Toaldo found that, according to the popular belief, the weather is much more variable at the time of new moon than at the other lunar periods. But convinced in advance of the existence of the influence that he wished to demonstrate, Toaldo attributed to the action of the new moon the changes in the weather occurring one or two days either before or after, whereas for the rest of the lunar period each day was considered separately. If, now, rigorous computations be made, giving to each day the same value, there will no longer be found any trace of the influence of the phases of the moon on the changes of the weather. During the past few years the study of the influence of the moon has been again taken up in a manner apparently more scientific. In the first place, all idea has been abandoned of finding any relations between the meteorological phenomena and the phases of the moon; that is to say, the synodic revolution which represents only the relative positions of the earth, the moon, and the sun. Then the anomalistic revolution was studied, which corresponds better to the respective real positions of the earth and the moon. But, above all, the position of the moon in declination has been compared, not with any special local meteorological phenomenon—such as temperature, rainfall, changes of the weather, etc.—but with the distribution of pressure over the surface of the globe as a whole.

The fundamental idea of these researches is that the movements of the moon in declination may lead to general displacements of the air or a balancing between the tropical regions and the higher latitudes, and thus cause periodical changes, such, for example, as in the boundary of the trade winds and in the law of change of pressure with latitude. We should then understand that a movement of a zone of high pressure, for example, might cause fine weather on one side of the zone and at the same time foul weather on the other side, and that these variations, which at first sight seem contradictory, might nevertheless be due to one and the same cause. These studies are, however, of too recent date and still too undeveloped to have already given results that may be considered as sufficiently conclusive and general. It is, however, interesting to mention them here, since by continuing to work in the same lines we may, perhaps, succeed in discovering the true relations between the moon and the phenomena of the weather, since the earlier researches have not brought about any positive conclusion. On the whole, in the present state of our knowledge, it can not be affirmed that the moon does exert any influence upon the weather, but at the same time it should not be denied that this influence may possibly exist. In any case it would show itself by complex phenomena, such as the displacement of the zones of high and low pressure, and might cause very different results in different regions.

In concluding the examination of the various opinions in regard to the influence of the moon, it may be well to say a word on the opinions concerning the lune roussée or harvest moon. This name has been given to the lunar period which, beginning in April, has its full moon either in the second half of that month or in the month of May; if there are two new moons in April it is with the second that the harvest moon begins. Agriculturists declare that often at that time, when the sky is clear and the moon shines brightly during the night, the tender buds are frozen and turn red, even although the temperature of the air does not fall below freezing; nothing of this nature occurs if the moon remains hidden behind the clouds. The explanation of this phenomena is very simple and the moon has no part in it. When the sky is clear and the atmosphere dry and transparent (this is the time when the moon shines most brightly), the temperature of bodies subjected to the nocturnal radiation falls far below the temperature of the air. If during the day the temperature has not been very high the nocturnal radiation may then chill the plants below freezing and they will freeze although the air remains at a higher temperature; on the other hand the plants will not be frozen if there are clouds to diminish the radiation. The conditions that lead to these freezings are, therefore, a clear sky and a relatively low temperature during the day. At the end of May or June the mean temperature is generally too high to allow us to fear these freezes, although they do occur sometimes. Before the commencement of the harvest moon—that is to say, at the end of March or the beginning of April—the temperature is lower than during the harvest moon itself; the conditions are, therefore, much more favorable for freezing by radiation; but as the vegetation has not yet begun these freezes do not cause any damage and do not attract any attention. We have here to do with a very simple phenomenon in which the moon plays no other part than merely to indicate by its brilliancy when the sky is pure and transparent.

In the countries in the south of France, where the vegetation is more advanced than in the center and the north, the critical period of vegetation is no longer during the harvest moon, but during the lunar period which precedes it.

OPINIONS REGARDING THE INFLUENCE OF THE SUN IN THE PRODUCTION OF RECURRING TYPES OF WEATHER.

Seasonal weather is a product of fixed astronomical causes modified by latitude, topography, and position with regard to land and water surfaces, and a belief is prevalent that departures from seasonal weather is due directly or indirectly to variations in the output of solar energy. There is also an inclination toward a belief that certain aspects of the sun may be responsible for certain types of weather, and it is deemed not improbable that solar conditions of causation may have defined periods of recurrence. At present, however, all is speculation regarding the relation of the sun to possible periodicities of the weather, and the employment of possible synchronous changes in solar and terrestrial conditions in the practice of weather forecasting necessarily awaits an accurate determination and association of conditions and changes of this character. Certain it is that claims of discoveries in this direction that may be made by men of standing in the world of science will be accompanied by proof of the discovery and of its applicability to practical work. In the meantime there are threads or traces of facts that justify further investigation, and in the conduct of this investigation the most approved methods and appliances and a most comprehensive appreciation of the latest advances in practical and theoretical astronomy and meteorology must be employed to achieve results.

Interest in the meteorological possibilities of a study of solar conditions has been particularly active during the last five years, and the literature of this period that summarizes practically all that has been accomplished in this work will be reviewed.

India presents a favorable field for comparison between solar conditions and meteorological phenomena, and the result of systematic and well-directed efforts to associate conditions of the sun, and more especially the appearance and disappearance of sun spots, with unusual delays and early terminations of the southwest monsoon rains is presented in the following extract from a paper by E. Douglas Archibald that appeared in Symon's Meteorological Magazine for July, 1900:

* * * Various attempts have been made to correlate the occurrence of Indian famines with the variations in the energy derived from the sun corresponding to the periodic changes in the spotted area; but though there are evidences of parallelism, the relation is not a simple or regular one. The condition of the sun is probably a contributory *vera causa*, but not a *maxima causa*.

Reacting conditions, initially determined by changes in the position of antarctic ice, slight deflections in the equatorial ocean currents and in the vertical and horizontal position of upper atmospheric air streams of abnormal condition, such as those recently shown to exist by means of kite observations, are likely to be far more potent prime causes of seasonal abnormals than the small and fairly regular changes which appear to follow the appearance and disappearance of sun spots. * * *

* * * Apart from these six-monthly barometric waves (referred to as having been observed at times in connection with Indian weather), there is little doubt that certain influences are at work in the atmospheric circulation over the Indian area which cooperate with other periodic factors in tending to cause excess or defect of rains at intervals of nine to twelve years. What these influences are it is difficult to say. To some extent they appear to be associated, as we have above noticed, with the 11-year period of sun spots; and certain irregularities of the two phenomena are. in my opinion, no argument against their convariancy, and even casual connection, since the northern and southern Indian areas are at seasons meteorologically distinct. So far as the facts go they may be summarized as follows:

1. Extensive droughts occur in the dry area of southern India, embracing in particular northern Mysore, south Deccan, southwest Hyderabad, but occasionally reaching Guzerat and parts of the Bombay and Madras presidencies, at intervals of nine and twelve years and usually, but not regularly, about a year before the sun-spot minimum. When the conditions are sufficiently acute famine occurs in the ensuing year.

2. A severe drought in the peninsula of southern India is followed by a severe drought and ensuing famine in northern India in about five cases out of seven.

This sequence is attributed by Mr. Eliot to the empirical law of opposition in the seasonal rainfalls of northern India and the general monsoon conditions of northern and southern India.

Thus a drought and high barometric pressure in southern India usually coincides with low pressure and heavy summer monsoon in northern India. This latter tends to be followed by a heavy winter rainfall, and this again by the compensatory law, first discovered by Professor Hill and the writer in 1877, by subsequent deficient summer rainfall in northern India.

3. Besides these, summer droughts tend to occur in northern India alone in years of maximum sun spots, connected in some way with the abnormal high pressure over western Asia which prevails at such epochs.

There is thus a double periodicity of drought and famine in north India and a single periodicity in south India in the sun-spot cycle, though the relation between the phenomena is too spasmodic and irregular to be utilized as a reliable factor for prevision.

Brückner's empirical cycle of thirty-five years, whatever its cause, undoubtedly exists in the Indian area. Under the title of the "grand cycle" it has long been known in Ceylon, and it is quite possible that the present famine, which from its area and the immense number (6,000,000) of people who are still on relief works appears to be the greatest famine of which we have any record, may be the aggregate effect of the simultaneous occurrence of a Brückner with a sun-spot cycle drought.

The problem is similar to that of the combinations of harmonic undulations which cause unusual tides, and its solution and application to prevision can only be effected by systematic study of the billows and ripples which appear in the long and short records of barometric pressure over wide areas for many years.

In a paper published by permission of the Secretary of the Smithsonian Institution in the Monthly Weather Review for April, 1902, C. G. Abbot discusses "The relation of the sun-spot cycle to meteorology" as follows:

Since the discovery of the periodicity of sun spots a large space in scientific literature has been occupied by articles tending to establish some connection between this and variable terrestrial phenomena. It is natural that it should be inferred that any considerable change in the sun must bring about numerous direct or indirect consequences upon the earth, but one who has given the subject no attention will be startled to find that the following list contains but a portion of the terrestrial phenomena asserted, on more or less authority, to be influenced by the sun-spot cycle: Magnetic and electrical conditions (including the aurora borealis), air temperature, barometic pressure, humidity, the winds, cloudiness, rainfall, depth and quantity of discharge of rivers, retreat and advance of galciers, number of shipwrecks, bank failures and commercial crises, the crops, prices of grain, famines, wars, and even flights of butterflies.

It would probably be easier to show that the number of articles concerning sun spots in scientific periodicals has an 11-year period than to prove all the above-mentioned relations to the general satisfaction. For the purposes of this paper it will be sufficient to assume as proven that terrestrial magnetism and the aurora borealis are affected when spots appear upon the sun, and that while the evidence is less simple in regard to the meteorological elements—temperature, barometric pressure, humidity, cloudiness, and rainfall—yet there is good reason to think that these, too, are somewhat connected with the sun-spot cycle.

HOW SUN SPOTS MAY BE ASSOCIATED WITH TERRESTRIAL PHENOMENA.

The question before us is this: Through what physical connection is the presence of sun spots associated with variations in terrestrial magnetism and with meteorology? The question suggests the possibility either of a single or a dual link between the solar and the terrestrial occurrences. It is conceivable, for instance, that the sun spots are associated with great electro-magnetic disturbances upon the sun which are propagated to the earth and directly disturb terrestrial electricity and magnetism, and that such a disturbance of atmospheric electricity as thus occurs may indirectly induce or prevent the accumulation of clouds, which in turn may bring on differences in temperature, barometric pressure, and rainall. Again, it is conceivable that sun spots are associated with an increase or a diminution of the sun's radiation, which obviously would directly affect meteorology, and indirectly might affect terrestrial magnetism and electricity. Still again, it might be that the sun spots are associated with great electro-magnetic disturbances in the sun and with an increase or diminution of solar radiation, and that in this dual way the terrestrial changes are directly brought about.

The second of these hypotheses is, I think, untenable as an explanation of the magnetic effects. These are too quick and pronounced to allow us to suppose for a moment that they are the indirect results of increased or decreased solar radiation. We may, then, admit that electro-magnetic disturbances are propagated from the sun at the time of sun spots. It would be difficult, however, to prove or disprove that these are competent to indirectly produce the observed fluctuations of temperature, pressure, and humidity which have been connected with the sun-spot cycle. Almost without exception writers on this subject who have ventured an opinion have attributed these meteorological changes to alterations in the amount of the solar radiation. There seems to be a preponderance of suggestion that the sun radiates more at sun-spot maximum, although there are not wanting many who hold precisely the contrary opinion.

METHOD OF DETERMINING THE SUPPOSED VARIABILITY OF SOLAR RADIATION—SOLAR ACTINOMETRY.

It would seem, at first sight, a simple thing to show whether the sun radiates more at one time than at another by a direct exposure of a suitable actinometer during a term of years. This has been done in several instances, but so far as I know with a wholly unconvincing result. About twenty years ago, for instance, two able gentlemen reduced, independently, such a series of observations extending over a sun-spot cycle and deducted, the one that the sun's rays were appreciably more intense at sun-spot maximum, the other the exact opposite. Nor are later results with the most perfect apparatus more convincing. * * * From observations extending back to the year 1883, taken at Montpelier, with the Crova self-recording actinometer, an instrument of highly approved construction and most ably and honestly used, large fluctuations in the curve are evident, but any connection between them and the 11-year sun-spot period, whose maxima occurred in 1883 and 1894, is hard to recognize.

EFFECTS OF ATMOSPHERIC ABSORPTION.

Shall we then conclude that the negative of the question is proved and that the solar radiation does not vary to any considerable extent periodically along with the presence of spots upon the surface of the sun? This conclusion would be premature. The observer at the earth's surface sees the sun much as a fish at the bottom of the lake sees the clouds. More than one-half of the sun's radiation which reaches the outer layers of the earth's atmosphere is reflected or radiated away or is absorbed within the atmosphere and fails wholly to reach the earth's surface except as heat produced by absorption and communicated chiefly by convection and precipitation. The atmosphere is constantly varying in its transparency. These changes are chiefly caused by water vapor, water globules, and dust becoming more or less abundant, and are so great that even the largest depressions in the curve of actinometer results just referred to might easily be thus caused. Indeed, it occurs to me, and may very likely have occurred to others, that the great depression in the curve for the years 1884, 1885, and 1886 was caused by the presence in the air of dust from the remarkable eruption of the volcano of Krakatoa in the summer of 1883.

In conclusion [Mr. Abbot remarks that], new views regarding the relation of the sun to meteorological phenomena point, like all their predecessors, to the complexity of the sun and the uncertainty of deductions based on our present knowledge. At the same time the probability of a vital connection between the solar changes and matters of great interest upon the earth has been more and more confirmed within the last thirty years. It would seem that satisfactory progress in our understanding of these relations requires that observations of the energy of the solar spectrum be carried on at the highest practicable altitude in or near the Tropics for a term of years that shall not be less, but preferably more, than a complete sun-spot period of eleven years. Such an investigation would determine, it may be hoped, whether or not the sun emits different quantities of radiation in different years; whether observations at lower altitudes may be relied upon to follow the sun's condition; and it might also throw light on the cause of solar periodicity.

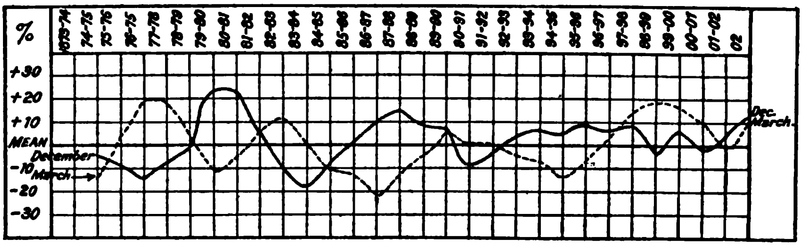
In the Transactions of the Toronto Astronomical Society for the year 1901, Prof. R. F. Stupart, director of the Toronto Observatory, discusses as follows investigations regarding the relations that may exist between sun spots and precipitation, as indicated by observations taken at Toronto and neighboring stations from 1830 to 1901:

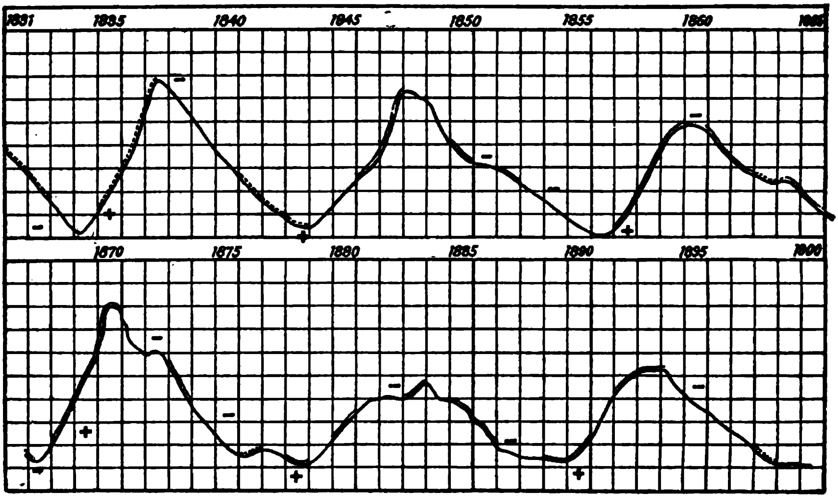
In order to test whether any probability of a connection existing between sun-spot periods and precipitation is indicated by the records of Toronto and neighboring stations, the writer has charted the sun-spot curve from 1830 to 1901, and also a precipitation curve obtained from the annual amount registered in the Lake Ontario basin. Between 1830 and 1842 an approximate value for the precipitation has been obtained from the records of Rochester and Marietta; from 1843 to 1860 the complete records at Toronto and Rochester, together with broken series at Buffalo and Oswego, have been used. From 1861 to 1873 continuous records at Toronto, Buffalo, Oswego, and Rochester were available. For the period between 1874 and 1901 Woodstock and Kingston, Ontario, were also considered. The sun-spot curve is that by Mr. William Ellis, F. R. S., published in the Proceedings of the Royal Society, March, 1898, volume 13, page 78.

The sun-spot curve had been doubled in those years that the precipitation exceeded the average mean amount of the whole series. Finally the + sign was placed opposite the years of greatest precipitation in each sun-spot period and the — sign opposite the years of marked deficiency. The result obtained is apparently instructive, as the combined sun-spot and precipitation curve seems to indicate a precipitation larger than normal for the two or three years immediately following the sun-spot minimum, and another pulse, less pronounced and more irregular, about midway between maximum and minimum; the sign + was found in every instance either at the sun-spot minimum or within three years following, and — signs were in each case found at sun-spot maximum or within two years of it, and again just previous to the minimum.

Summing up these results it would appear that in the Lake Ontario basin the precipitation is likely to exceed the normal during two or three years immediately following the sun-spot minimum and again about three years after the maximum, and that it is likely to be somewhat less than normal about sun-spot maximum and during a few years preceding sun-spot minimum.

As a close connection probably exists between precipitation and the movements of high and low pressure, and, indeed, between precipitation and mean pressure values, as a preliminary investigation, the movements of low areas during the months of December and March in each of the years between 1873 and 1901 were tabulated, the total number in each year being divided into groups comprising those areas which were first observed in the northwest States or Territories; those which were first observed in the western States and those which were first observed in the southwest States or Gulf of Mexico; percentages showing the relative frequency of the areas in the various groups in each of the months of the whole period under consideration were thus obtained and a curve drawn. A very evident maximum of southwest areas in December is shown in 1878–79, 1884–85, and 1894–95; and for March in 1876–1878, 1883–84, 1890–1892, 1897–1900. On plotting curves showing percentages of areas other than from the northwest States and Territories, it would seem that the March curve is very nearly the reverse of that for December. Corresponding curves for June and September are in course of preparation, and subsequently all months of the year will be considered.





It is conceivable that a varying solar heat radiation during a sun-spot cycle may cause appreciable changes in the movements of high and low pressure areas, changes perhaps largely influenced and governed by a fluctuating intensity and position of the subtropical belt of high pressure in corresponding seasons of different years. While the curves already plotted seem to indicate a connection between annual precipitation and sun spots, it is quite possible that a comparison of the corresponding seasons during several sun-spot cycles may show a much more evident connection between sun-spot and meteorological phenomena. Possibly a contraction of the subtropical high during sun-spot minimum may tend to a more than average number of low areas developing in the Southwest while the sun is south of the equator and a diminution in the number and intensity of storms during the warmer seasons when the sun is north.

STELLAR INFLUENCES AND PLANETARY METEOROLOGY IN LONG-RANGE WEATHER FORECASTING.

The long-range weather forecasts of the ancients, that have in modern times been referred to by uninformed persons as one of the lost arts, consisted merely of an association of the seasons with the appearance of certain heavenly constellations, and the extent to which seasons were favorable or unfavorable to agricultural or other pursuits fixed the beneficent or malevolent character of the influences that were ascribed to the stars with which they were identified. During the last few hundred years, however, or since the establishment of the sun as the dominating body of the system of which the earth is a part, and since exhaustive tests have shown that the influence of the stars on the phenomena of the earth's atmosphere is practically inappreciable, no serious attempt has been made, even by so-called long-range weather forecasters, to ascribe to the fixed stars a causative influence on terrestrial weather.

Modern advocates of the ancient art of star divination, or astrology, now form a class of fortune tellers whose success depends, as it did thousands of years ago, upon a more or less deeply rooted inherent belief in the superstitions that find lodgment in the average human breast. Trading upon this belief certain men write and talk learnedly (?) and wanderingly regarding eclipses, occultations, and various planetary combinations, accounts of which they cull from almanacs, and ascribe thereto, for a pecuniary consideration received from a credulous or ignorant and unobserving constituency, influences and effects upon our weather that are absolutely hidden and undiscoverable by any known method or system of examination or comparison. These facts regarding alleged planetary influences are presented with an unimpaired belief that they will not in the least weaken the inherent yearning for the mystical referred to, that leads men to subscribe literally and liberally to the support of artful assumers of superhuman knowledge.

Meteorological literature is deficient in references to planetary influences on the weather, and from this fact it may be assumed that long-range forecasters fear to enter a field where deductions are subject to mathematical demonstration, and where claims of superior knowledge will be confronted by established or recognized facts pertaining to the more exact science of astronomy. There are of a necessity exceptions to this rule, and the plea for entering the field is invariably an assumption of knowledge that is universally recognized as being beyond the present scope of astronomy.

In concluding remarks under this head it may be stated that while there is no evidence that the planets of the solar system have a direct controlling influence upon terrestrial weather, arguments have been presented to the effect that they are factors in the production of sun spots and may be, therefore, indirectly and distantly connected with variations in barometric pressure and magnetic force. The connection has not, however, been established; and however fascinating the vision of forecasting possibilities that would result if a knowledge of the relation of the weather to sun spots could be supplemented by exact calculations of the existence of causes that produce sun spots, the fact that the former connection has not been determined necessarily points to a concentration of effort to solve the first step before advancing to the second step in this extremely complex problem. And it is in the complexity of the problem that long-range forecasters find a refuge. They possess a degree of acumen that enables them to avoid explanations of methods and results along lines where demonstrated explanations are not possible, and to resort to vague references regarding disturbing and imperfectly understood planetary electrical influences, apexes of planetary disturbances, etc., when called upon to explain failures in the operation of their alleged systems or to reply to inquiries regarding the basis upon which they are made.

WEATHER INDICATIONS AFFORDED BY ANIMALS, BIRDS, AND PLANTS.

Observations of the habits and conditions of animals and birds and the appearance of plants have a recognized value in determining the character of past weather and, to a limited extent, the weather for a few hours in the future. In a state of nature the condition of animals and plants is an indication of the character of past weather, so far as it has affected their physical condition in the one case and their growth and preservation in the other. The appreciation of animals and plants for future weather must necessarily be limited to the effect or influence upon their organizations of present atmospheric conditions, and in the case of animals the sensations that are produced by certain conditions or variations of atmospheric moisture, pressure, temperature, etc., are instinctively associated with the kind of weather that usually follows the kind of sensations experienced. Neither animals nor plants can possibly be affected by the weather of a future month or season.

Undomesticated or wild animals, fowl, and birds are usually used as an observational basis for long-range forecasts. Animals, such as the ground hog, or woodchuck, and the bear, that make winter a season of hibernation, are supposed, by the character of their preparations and the time of their retirement, to indicate the length and strength of the cold of the approaching winter, and toward winter's close they again become prominent factors in this scheme of forecasting. For, according to weather folklore—

> If, on Candlemas day the weather is bright and clear, the ground hog will stay in or return to his den, thus indicating that more snow and cold are to come (and there he stays for a period that varies in length in the different sayings that relate to this act from two to six weeks); but if it snows or rains he will creep out, as the winter is ended.
>
> The bear comes out on the 2d of February, Candlemas day, and if he sees his shadow he returns for six weeks.

If the sayings regarding the coming out of the ground hog and the bear on Candlemas day possess any merit, it rests upon the fact that fine and clear days in the early part of February are usually cold days, and that cloudy weather at that season is likely to prevail during warm days. The animals in question therefore consult their own comfort in cases where they make a premature exit from winter quarters. If it is cold they return; if it is not cold they remain out until the inevitable return of cold weather, which at that season will not be delayed many days.

The thickness of the fur of fur-bearing animals is also used as evidence of the character of the approaching winter, when, as a matter of fact, this depends absolutely upon "the physical condition of the animal, and his physical condition depends upon the weather of the past and the extent to which it has affected his food supply and general health, rather than upon the weather of the future."

The accumulation of food by squirrels, beavers, and other animals during the autumn months is also taken as a guide to the character of the coming winter. It is assumed that the gathering of a large supply of food indicates a long, hard winter, and vice versa. Careful observations of the habits of animals show that the autumn habits referred to or their omission bear no relation to the character of the following winter. The quantity of nuts stored by squirrels is governed by the supply of nuts at their disposal. In seasons when the crop is abundant the busy little animals will gather a large quantity, and when nuts are scarce his accumulation will be correspondingly small. The supply of nuts is governed by past and not future weather.

Birds of passage migrate to the south with the first breath of winter, or when their food supply is affected by inclement weather that is peculiar to approaching cold weather, and return north when spring sets in in the south. That their flights are influenced by present rather than a knowledge of future weather conditions is evident to all observers. Their judgment is on a par with that exhibited by some men in doffing or donning winter clothing; their actions are dictated by a sense of personal comfort, and they are often compelled by actions to admit their error. The thickness of plumage on wild and domestic fowls is also a result of feeding and past conditions of weather, rather than an indication of the character of future weather. And the goose-bone theory is one on which no two geese agree.

Moss, bark on trees, and the thickness of nut shells, pumpkin rinds, etc., furnish another basis for long-range weather speculations that also confuse and misinterpret conditions that are due to past conditions and have no bearing on future weather. There is one feature of tree weather forecasting, however, that possesses merit in so far as it presents as a basis a record of the general character of the weather for many years, and may thus show or indicate recurring seasons of certain kinds of weather. Trees of great age and large growth, like the sequoias, indicate by their rings years that have been favorable and unfavorable for their growth, or, in other words, wet and dry years in the region in which they are located, and thus establish a record of the seasons that may be useful in calculations for the future.

In passing, it will be noted that prominent advocates of this branch of long-range weather forecasting have long since disappeared from public view, which fact may be taken as indicating that dishonest practices can be profitably conducted only by the possession, or an assumed possession, of superior knowledge, or under a cloak of mysticism, and not in connection with matters concerning which ordinary observation will reveal the truth.

ESTIMATES BASED UPON DAYS, MONTHS, SEASONS, AND YEARS.

There are several valid reasons for assuming that the weather observed on certain days may indicate the character of the weather for certain subsequent days. The first of these is that in the middle latitudes of the globe well-defined atmospheric disturbances or general storms of greater or less intensity average about one in each six or seven days; the second, that marked departures from the average weather occurring on one day, or on two or three consecutive days, are likely to be balanced by reverse abnormalities in the near future; and the third, that the general average duration of warm waves and cold waves, which are attendant features of areas of high and low barometric pressure, is three days. The seven-day period also corresponds closely with the moon-phase periods, which admittedly have a slight effect upon rainfall (too slight, however, to be considered in daily forecast work).

The assumed or supposed six or seven day period of recurring weather is indicated by the common saying, "If it rains on the first Sunday in the month it will rain every Sunday in the month." This saying possesses value in so far as the weather may conform, in particular instances, to a general average, and the likelihood of the weather conforming to this extent to general averages is not sufficiently great to justify the employment of the chance in actual forecast work. Forecasts for two to three days in advance, made in the full light of present knowledge, must be based upon actual existing atmospheric conditions that prevail over great areas, and they represent calculations of changes that will occur within the areas; they deal with average conditions only so far as a recognized tendency on the part of the weather to return to average conditions may be considered. Sunday was doubtless selected, in the saying quoted, for the reason that the weather and its seasonal or unseasonal character is more closely observed and studied on certain days, notably on Sun-days and holidays, when men's minds are not occupied with their usual pursuits; any other day in the week will answer as well for this form of estimating the weather of the future.

Long-range weather forecasters, for purposes of mystification, attribute the six and seven day period to the moon's influence. They time their disturbances six or seven days apart, start them on the Pacific coast and carry them by regular stages across the United States, assuming in each case a conformance to general averages. Equal accuracy or inaccuracy in the forecast would result if they started the disturbances in the central valleys or on the Atlantic seaboard on corresponding dates, or introduced them on the Pacific coast on dates intermediate to those they select. By claiming, for verification purposes, a day or two on either side of the dates specified, by carefully avoiding specific forecasts of rain for specified days and districts, and by calling attention to hits that will occasionally be made under any system of chance, and never referring to misses, they successfully pursue in these enlightened times the practices of the fabulous age.

The six and seven day weather periods have been subjected to a rather searching examination by H. Helm Clayton, and the results of his examination are given in several publications, but principally in the American Journal of Science and Art. It may be noted in this connection that Mr. Clayton for a time actually published forecasts based upon his conclusions, which were not, apparently, satisfactory as regards results nor convincing as regards a confirmation of any theory he may have held.

Investigations and conclusions based upon honest and thorough examination and comparison of meteorological records show that generally recognized, though ill defined, six and seven day periods of recurring weather can not be utilized for making definite forecasts for specified days and localities. Assuming that forecasts of rain or fair weather, warmer or colder, based upon the results, would yield a slightly higher verification than unqualified guesses—which, if made in sufficiently large numbers, would naturally verify in one-half the cases—there is no evidence presented by the investigations that the character or intensity of the disturbances that attend the barometric minima can be determined. A knowledge of the probable order of succession of barometric depressions for periods of one to four weeks in advance would greatly assist the forecaster, and as a matter of fact the probability of the succession has been given due weight and consideration by the Weather Bureau for many years. Experience in actual forecast work has shown, however, that rules that are subject to 50 per cent of exceptions are, like theoretical deductions, dangerous factors to employ in the work of weather forecasting. And aside from conclusions that have been or may be reached regarding systems or methods of forecasting merely weather and temperature, the fact remains that forecasts of this class are of small importance when considered in connection with forecasts of severe storms, etc. In fact, the value of weather forecasts is fixed by the degree of accuracy that is attained in predicting gales, cold and warm waves of marked severity, heavy snow, heavy rain (and floods resulting therefrom), frost, and other atmospheric phenomena of an unusual or exceptional character, and long-range forecasts that are calculated to be of special value to commercial and agricultural interests must specify these occurrences for specified sections, and to this end honest endeavor is being directed.

A casual examination of published long-range weather forecasts shows clearly that the success of the systems depends absolutely upon a conformance of the weather to six or seven day periods with modifications called for by seasonal averages and chances, and the fact that in about 50 per cent of the cases the periods are not revealed and that fully one-half of the forecasts are misplaced in the periods that do appear proves to conservative minds the unsoundness of the systems. It is apparent from reports of investigations that have been made that there is a tendency on the part of investigators to assume the six and seven day periods and to then endeavor to fit the periods to moon phases or positions, solar rotations, etc.

Estimates of future weather that are based upon the character of certain days have their origin in fancy or superstition. As a rule the days selected are church or saints' days or holidays, and it is apparent that the selections have been governed by the prominence of the days. As a basis of calculation the weather of certain days is of value—

> only so far as it may be assumed that normal weather conditions on those days are favorable and abnormal conditions are unfavorable for seasonable weather in the near future. They may be considered as indicating which way the balance of temperature and precipitation tips at that particular season of the year, and the forecasting feature is found in the statement of weather conditions that will be required to adjust the balance.

Individual months are taken as a basis of prediction for succeeding months or seasons, and all estimates of this character that possess merit speculate merely on normal tendencies of the weather at certain seasons, and, like estimates based upon the character of days, assume that normal conditions are favorable and abnormal conditions unfavorable for seasonal weather in future months, seasons, or years. In fact, the entire scheme of long-range forecasts that are based upon the condition of the weather during certain periods, whether long or short, depends upon an assumed inviolable law of compensation. This assumption is, in a degree, justified, but for purposes of specific forecasts it possesses little value. Records of meteorological observations taken at given points show that the temperature and rainfall of single years and series of years conform closely to normal values and that the greater the period the smaller are the departures. Conversely, the shorter the period the greater the departures that are sometimes shown, until for periods of a month or less it is impossible to calculate to what extent abnormal features may predominate. There is a popular impression that a warm winter will be followed by a cool spring or summer, and a hot summer by a cool autumn or winter, but the succession so indicated will not occur in more than 50 per cent of any large number of cases that may be noted. The question may here arise, How, then, can compensation be made for extreme abnormal conditions for days, months, or seasons? The answer is that it is not necessarily made in any one month, season, or year. For instance, in the Middle Atlantic States the summers of 1901, 1902, and 1903 were cool, and the winters of 1900-1901, 1901-2, and 1902-3 were moderate, while the winter of 1903–4 was probably the coldest in the history of that section. The question now arises, What period in the preceding three years could have been used as a basis for forecasting an exceptionally cold winter in 1903–4?

Examinations of records show that excesses or deficiencies of temperature or rainfall in any season do not necessarily indicate opposite excesses and deficiencies for any given future period, and that when compensation is made for excesses or deficiencies it is made gradually and almost imperceptibly as often as in the form of marked opposites.

PREDICTIONS BASED UPON OBSERVATIONS OF OCEAN CURRENTS.

The influence of ocean currents, notably the Gulf stream and the Japan current, upon the weather and climate of western Europe and western North America, respectively, has been discussed in numerous papers, and the belief has been expressed that observations of variations in the Japan current could be made a basis for forecasting California weather for several months in advance. The opinion has also found expression that the course of the Gulf stream, with particular reference to its north and south shifting over the western Atlantic, had a controlling influence upon West Indian hurricanes and even furnished a basis for predicting their periods of frequency and intensity.

The general subject of ocean temperatures and meteorology, based upon a paper by Sir John Murray that appeared in the Geographical Journal for August, 1898, published by the Royal Geographical Society of London, is considered, in brief, in the Monthly Weather Review for July, 1898. After summing up data of ocean temperatures and comparing these temperatures with those obtained over the continental areas, the editor of the Review concludes as follows:

> At first thought one would expect to find in Doctor Murray's lines of equal annual temperature range some traces of the course of the Gulf stream and Kuroshiwo (Japan current), but it is only the changes in the positions of these

currents that can produce ranges of temperature, and these changes are so largely controlled by the wind that Doctor Murray's charts show us principally the effect upon the ocean water of the changes in the atmospheric circulation. This same principle applies also to the closed seas, such as the Mediterranean and Baltic, the Red Sea, and the Persian Gulf, in all which cases a larger range of temperature is observed at the head of the sea than at the mouth of the sea, due to the fact that the highest temperatures occur at the head when the wind blows toward that direction in the summer, and the lowest temperatures when the wind blows in the opposite direction at the opposite season of the year. There is, therefore, in this map no comfort for those who maintain that the Gulf stream or the Kuroshiwo, respectively, alleviate or control the temperatures of the eastern portion of the Atlantic and Pacific oceans and the adjacent portions of Europe and America, respectively. Everywhere we see that it is the wind that controls the temperature of the surface of the ocean, and then carries this ocean temperature inward over the land. The same applies to the Southern Hemisphere, where Doctor Murray's chart shows that the greatest range of ocean temperature is in the regions where there is the greatest annual range of wind direction.

In the August Review of 1898 Professor Abbe refers as follows to studies of the Japan current:

We notice in several California papers earnest articles advocating the study of the Japan current and its relation to the weather of the Pacific coast. Especially does Mr. W. S. Prosser, of Auburn, Cal., state that in 1878 or 1879 he suggested this very thing and urged favorable action on the authorities at Washington.

It ought hardly to be necessary to assure the citizens of the Pacific coast that the Japan current, like the Gulf stream, has been studied with much care by the navigators of all nations, and charts have been published showing the temperature and the movement of the surface water, not only for these special currents, but for the whole of the surrounding ocean for each month in the year. These charts show that without any doubt whatever the currents as such soon dwindle away, and all that is left is a very slow movement of the water to and fro with the wind. It is the west wind that strikes our Pacific coast, and not the Japan current. This wind brings moisture from the Pacific Ocean, and not from the neighborhood of Japan. It is these moist winds, and not the ocean currents, that control the climate of California.

The hydrographic offices of all nations are engaged in the study of ocean currents and surface drifts as such, including their dependence upon the winds. The meteorologist studies the winds as affected by the surfaces of the land and ocean, but he finds the atmosphere moving so rapidly and its various portions so easily intermixed with each other that it is at present impossible to tell whether the moisture brought by the wind to California comes from the Pacific Ocean in general or from the Japan current especially. In fact, it matters little to him where it comes from. He has to take it as he finds it over California, and then decide whether it is rising and cooling to form cloud and rain, or whether it is descending and likely to stay unprecipitated. The important features of the weather of California depend principally upon whether its winds are descending and being pushed outward from a high and dry area to the northeastward, or whether they are descending and coming from moister air to the northwestward. It is the air supplied from the high-pressure area on the southwest, between California and Hawaii, that gives the former her long-continued spells of dry, clear weather. The length of these spells may depend, in a general way, upon atmospheric conditions, not on the condition of the ocean.

In the fall of 1898 the writer remarked on the Japan current as a controller of California weather as follows:

> The subject of long-range weather forecasts has recently gained attention by reason of a suggestion of Professor Hammon, of the Weather Bureau office at San Francisco, that possibly the character of the seasons in California can be successfully forecast by a study of the Japan current.
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> In examining reports of meteorological observations made in the Aleutian Islands he discovered an apparent relation between abnormal air temperatures in those islands and periods of drought and excessive rainfall in California. He associated unusually high temperature in the north with subsequent periods of drought in California, and unusually low temperature in the north with excessive rains in California. In seeking an explanation of these apparent relations he concluded that periods of high temperature in the Aleutian Islands indicated a northern course of the Japan current, whereby the heat of that current was, in part, lost, causing it to arrive off the California coast possessed of unusually low temperature, giving drought in California; and that abnormally low temperature in the Aleutian Islands indicated a southern course of the Japan current, which, in following this course, retained its heat and arrived off the California coast possessed of unusual warmth, thereby causing excessive rains in California. He calculated that if the succession of these conditions could be established by further observations, three months' foreknowledge of the character of the weather in California could be given and that the fruit and grain industries of that State would be benefited by the forecast to the extent of millions of dollars annually.

Professor Hammon's merely preliminary investigations, and the theory which has evolved from them, naturally lead to the question, Can long-range forecasts of California weather be based upon observations taken along the Japan current? The solution of this question is dependent upon the establishment of the following facts: That there are periods during which the water of the ocean off the California coast is unseasonably warm or cold, that these periods are associated with periods of excessive rains or drought, respectively, in California, and that periods of warm and cold ocean temperature and of excessive moisture and drought in California are associated with periods of abnormally low and high air temperatures at points in the north which border the course of the Japan current.

As regards the first fact to be established, there are no known data which show that the temperature of the ocean water off the California coast is subject to unseasonable or abnormal changes in temperature; and we are not permitted to associate possible but unknown changes of this character with California climatic changes, nor with abnormal air temperatures over the Aleutian Islands. We are, in fact, confined to an attempt to associate periods of unusually high and unusually low air temperatures over the Aleutian Islands with periods of drought and excessive rains in California. Owing to very meager data it is not possible to establish these relations; it is not possible to say whether the apparent relations discovered by Professor Hammon were accidental or resulted from a law of nature.

In the Philadelphia Press of October 5, 1898, Mr. Harvey M. Watts remarks upon the deductions of Mr. Hammon regarding the influence of the Japan current on California weather as follows:

> The Weather Bureau has had the question of long-range weather forecasts once more brought to its attention by the California State Board of Trade. Every once in a while the problem and possibility of seasonal forecasts is discussed but to be negatived by present knowledge. That an approximately correct seasonal forecast would be of enormous benefit to agriculture is unquestioned, and it is this that impels the Californians to ask the Government experts to look into the matter, for they believe that the observer at San Francisco, Mr. W. H. Hammon, has discovered the determining factor in the seasonal variations of California weather. With this factor known and its variations recorded the possibility of forecasting wet and dry years opens up a new future for agriculture, as it reduces useless experiment and heavy losses due to climatic vagaries.
>
> The seeming fact that has been worked out by Observer Hammon is that there is a close connection between the shifting of the Japan oceanic current and the wet and dry seasons along the Pacific coast. When the Japan current is deflected to the north, according to Mr. Hammon's theory, it gives up its warmth to those regions and arrives off the Pacific coast cooled down to such a degree that little evaporation results and the year is dry. If the current keeps moving along the lower latitudes its effect is felt in the increased warmth, moisture, and precipitation along the lower Pacific coast line and a wet year is experienced. This relation, as determined by Mr. Hammon, takes three months to show its effects, so that the Californians believe that a cable laid to one of the Aleutian Islands would enable the United States observer at San Francisco to forecast the summer conditions for California by a study of the spring conditions 2,000 miles to the northwest. In this way millions might be saved by means of a general seasonal forecast, which would enable agriculturists to prepare for the worst or make ready for a bountiful return under favorable weather conditions.
>
> Without going into the merits of Mr. Hammon's deductions for the moment, it should be said that extended observations either with or without a cable in the Aleutian archipelago will well repay any outlay the Weather Bureau may ask Congress to make. Not only the Pacific coast weather, but the seasonal conditions of the entire Northwest, the upper Mississippi Valley, and, to a certain extent, the watershed of the Great Lakes are forecast in the conditions that prevail in the northern Pacific Ocean. It is from the northern Pacific that the continental storms move in that play so important a part in the climatology of the United States. And it is the shifting of these oceanic areas of low barometer relatively to the high barometer over the interior of the continent in British America that makes up the alternations of warm and cool, wet and dry weather that are daily displayed on the United States weather maps. To attribute the variations of climate due to these great atmospheric swirls to an oceanic current, however, seems an error, though it is the same kind of an error that for so many years attributed to the Gulf stream a determining effect on the climate of all western Europe. As the results are out of all proportion to the cause, the Gulf-stream theory has been generally abandoned, and it would seem that Mr. Hammon's Japan-current theory would suffer a like fate, for it is the general eastward atmospheric drift and not the trend of the oceanic currents that determines the climate.

However, even if one throws overboard the Japan current, it does not in the least destroy the possibility of forecasting weather conditions in the United States by means of observations in the Aleutian Islands. There our weather is brewed. There the great changes occur—the deflection of the Japan current probably being an incident—that are felt later on our coast and continent. To study them, to discover any rhythm in their yearly or secular variation, is to get at the secret of long-range forecasting. This work is one of vast importance, not only for California but for the greater part of the United States, where the weather is controlled by the circumpolar circulation. To make sure, however, of the accuracy of these seasonal forecasts a wide outlook must be maintained. In India, the only country where such forecasts are attempted, the atmospheric conditions over Persia, southern Africa, and Australia play an important part in drawing conclusions. For us it must be the northern Pacific and the Athabascan region. And to get at the former let us have the Aleutian stations by all means.

In a letter dated February 19, 1904, the honorable Secretary of Agriculture answered a communication of Mr. W. S. Prosser regarding the importance of investigations of the influence of the Japan current on the weather of the Pacific coast of the United States as follows:

Your letter of the 8th instant, urging the importance of studying the influence of the Japan current upon the weather conditions of the Pacific coast, has been received and given careful attention. You are quite right in your statement that an accurate forecast of the rainfall of California a season in advance would be extremely valuable to the people of that State. I can not assent so readily, however, to your second proposition, viz, that the climate of the Pacific coast depends upon the Japan current, as that of England depends upon the Gulf stream. Persons who have given the matter careful study and should, therefore, be in a position to speak advisedly are not willing to admit that either the Gulf stream or the Japan current, as such, exerts any appreciable influence upon the climate of the shores opposite its origin. It is quite true that the general oceanic influence is a powerful one on the shores of western Europe and western America. The popular error in regard to the matter is twofold in its nature. In the first place, the public generally has a very inadequate idea of the true nature of both the Gulf stream and the Japan current. The mistake is generally made of giving both of them throughout their entire course attributes which they possess only at and near their origin. In the second place, the popular mind ascribes to the two currents under consideration, which form only a small part of the great oceans in which they course, effects which truly belong to the oceans as a whole and not to an insignificant part of them. Within the last half century organized effort has been put forth in various parts of the world to obtain accurate data as to the weather conditions and currents of the great oceans.

Out of all this effort has come certain facts that satisfactorily explain the broader principles of oceanic circulation. First and foremost of these is the effect of the wind upon the ocean waters. Throughout a broad belt on the earth's surface, say from twenty degrees south latitude to thirty degrees north latitude, the winds are persistently from some point in the eastern semicircle, and it is in this region that the great oceanic currents have their origin. In the Northern Hemisphere the surface waters, under the influence of the northeast trade winds, have a decided set from the northeast or east, and there is formed what is known in both the Atlantic and Pacific oceans as the north equatorial current. This current, or drift, as it might be called, is due to the direct action of the wind on the water. In the North Atlantic the surface drift from the northeast heaps up the water in the Caribbean Sea, and since it can not escape to the westward the overflow is forced to the northeastward through the Florida Straits, and thus forms the Gulf stream. This stream, as it emerges from the Gulf of Mexico and passes northward between Florida and the Bahamas, is only indirectly caused by the wind. In its lower reaches the wind is powerless to change its direction, but it may, and often does, accelerate or retard its velocity. In the North Pacific Ocean the north equatorial current impinges on the eastern shores of Formosa and adjacent islands, the greater portion, however, passing into the China Sea. The remaining portion is deflected northward along the eastern shores of Formosa until it reaches about twenty-six degrees north latitude, where it bears off to the north-northeast, washing the southeastern shores of Japan and then moving northeastward with diminishing velocity it merges with the general easterly drift of the North Pacific.

The existence of the so-called Japanese current in the North Pacific is perpetuated during the season from March to September by the prevailing southwesterly winds, but when these fail, as in the months of October to February, the current as such becomes uncertain and variable, its direction and velocity depending largely upon the wind experienced from day to day. I have entered into this detail in order to make clear that the great ocean currents are created primarily by the wind, and that in themselves they can not have the dominating influence on the weather that is often ascribed to them. The influence of the Pacific Ocean on the climate of California is, of course, understood. It tempers the winds of winter and protects a large portion of the State from frosts and snows normal to the latitude, and in summer the moist, cool winds bring cloud and fog along the coast, and this it does from year to year without perceptible change. The great ocean itself, with its thousands of miles of water surface, is the important factor as regards the climatology of the State. The temperature of the ocean waters changes but little from year to year; whatever slight variation there might be in the temperature of the so-called Japan current would not, it is believed, have the slightest effect on the rainfall of California a year hence. I do not underestimate the value of seasonal forecasts, nor am I unwilling to set on foot investigations that give promise of even a small degree of success. The progress of science is necessarily slow, but let us continue to hope that the problem may be eventually solved.

For further information relative to the effect of the oceans on land climates you might read an article by Professor Moore, Chief of the Weather Bureau, in Encyclopedia Americana, a publication just now coming from the press.

A CONSIDERATION OF ATMOSPHERIC PRESSURES IN WEATHER FORECASTING.

Many well-informed meteorologists are of the opinion that the next advance in the art of weather forecasting will be accomplished by a correlation of the greater and lesser areas of high and low barometric pressure of the Northern Hemisphere or of the globe. The forecasts now issued by meteorological services are based upon skill acquired by study, observation, and experience in calculating the development, movements, increase, and decrease in intensity, and magnitude of areas of high and low barometric pressure that appear within areas covered by the telegraphic reports of the several services. The dependence of these lesser high and low areas upon the greater or continental and oceanic so-called permanent areas of high and low barometric pressure is recognized, and the fact is admitted that a knowledge of the character and movements of the greater masses of the earth's atmosphere, as represented by the continental and oceanic seasonal high and low areas, is essential to calculations of weather conditions in any given section or locality for periods greater than two or three days in advance. For it is apparent that upon the exact location and magnitude of these greater high and low areas for a day, week, month, or season does the character of the weather in the regions they dominate depend. For instance, a slight shifting to the westward of the summer North Atlantic high area gives unusual heat and generally dry weather over the eastern portion of the United States. If the center of the high area shifts to the westward south of its usual position, as regards latitude, the heat is general from the Gulf of Mexico to Canada; if the center occupies a more northern latitude in its western position the heated area is confined to the more northern districts of the eastern portion of the United States, and the South Atlantic States receive the benefit of easterly winds from the ocean. When the Atlantic high area occupies an easterly position over the ocean, or exhibits pressures below the normal, cool weather for the season, or at least variable temperatures, are experienced over the eastern portion of the United States. In fact, the North Atlantic high area controls to a great degree not only the summer weather of the greater part of the United States, but also the course and character of West Indian hurricanes.

Winter types of weather over a great part of the middle circuit of the Northern Hemisphere are undoubtedly dominated in a greater or less degree by the great Asiatic area of high barometric pressure. In the middle latitudes the movements or swingings of this vast mass of air is to the westward; when it moves or extends over the northern portion of Europe North Atlantic storms are likely to be deflected toward southern Europe, and cold, stormy weather is experienced over southern European countries; when it extends westward over southern Europe North Atlantic storms follow a course toward the Scandinavian coast, and moderate temperatures are experienced in central and southern Europe. When the great continental high area extends westward over west-central Europe and the British Isles it checks the succession of North Atlantic storms, and finally affects the rate of progression of high and low areas over the United States. In its normal winter distribution atmospheric pressure is higher over southern Europe and relatively low over the northern, and especially over the northwestern countries. Under these conditions of atmospheric pressure the progression of storms from the Atlantic is normal; when, however, this arrangement of pressure is reversed or distorted, abnormal storm movements and features will be observed. At times, also, when the air masses up over western Asia and continental Europe the advance of Atlantic storms is checked, resultant low barometric pressure prevails for periods of several days over and near the British Isles, high pressure builds up over the middle longitudes of the Atlantic, and the eastward progress of high and low areas over the United States is retarded. It has been found by observation that this retardation of the usual progression of high and low areas over the eastern half of the United States continues several days after evidence appears of a return to normal barometric conditions over western Europe.

The influence of the Asiatic winter area of high atmospheric pressure is recognized in all studies and calculations regarding Asiatic weather and climate. The spring and autumn monsoons of the southern countries of Asia are directly associated with the breaking up in the spring and the building up in the autumn of the great interior air mass, and a solution of the problem of forecasting the time and character of the monsoons rests upon the ability of the meteorologist to foresee the nature of the changes that occur in Asiatic atmospheric pressures.

OPINIONS AND DISCUSSIONS OF THE GENERAL SUBJECT OF LONG-RANGE WEATHER FORECASTS.

Under the title "Imperial meteorology," in Nature (vol. 69, pp. 537–538), recent progress in meteorology is discussed as follows:

> Slowly, but still step by step, the science of meteorology progresses, and new visions are opened up which suggest bright prospects for future possibilities, but which also lay exposed the lost opportunities of the past. Like every other science, the modern methods of observation (or at any rate the chief meteorological elements) are nearly all that can be desired, but when it is required to revert to observations made more than thirty or forty years ago, how lamentably few are the records and how uncertain in many cases are their accuracy. Further, anyone who has had occasion to hunt up early series of observations of pressure, temperature, rainfall, etc., will have been struck with the common occurrence of breaks extending here and there for one, two, three, or more years. Nevertheless, it is little use crying over the past, but strenuous efforts should be made in the future to see that the needed observations should be secured.
>
> The more the variations of the weather are studied the more is the idea strongly impressed on the investigator that these variations from year to year are not mere matters of chance, but are produced by a cause originating outside the earth's atmosphere, and with little doubt from the sun, naturally the prime factor and father of all the important weather changes.
>
> His apparent daily journey round the earth, caused by the latter's rotation, is the origin of all the diurnal changes familiar to meteorologists.
>
> The earth's journey round the center of our solar system is again the origin of all the other meteorological variations called seasons which pass through their phases in a year.

From year to year, however, these daily and yearly variations, although they preserve more or less their original variations as regards their lengths of period, change in amount sometimes to a very great degree and cause one to speculate on the probable kind of weather for the following year.

The view that these changes from year to year are due to the direct or indirect action of the sun has a very great degree of probability in its favor, since we know that this highly heated body is in an active state, as deducted by the numerous and varied solar phenomena that have been observed. Further, the periodicities deduced from long series of solar observations have added another link in the chain of evidence showing that the sun's heat must be constantly varying, a fact which it is necessary to prove before solar influence can be put forth as a possible source of the terrestrial changes.

It is the work of the now numerous magnificent meteorological institutions spread over the globe for each to gather into its own particular net the meteorological changes that are occurring in its own area, and by means of these facts to forecast what kind of weather may be expected either on the following day, week, or month, or as far ahead as possible. Many of these institutions for several years found that their own areas were too limited in extent to give them the necessary data for the work in hand, and so entered into a mutual compact with neighboring countries for the exchange of certain pieces of meteorological information.

The present stage of meteorological investigation has in the last few years indicated that even this mutual help of the neighboring countries, each working for its own immediate ends, is not sufficient for a satisfactory solution of world meteorology.

" The next development of weather study will almost certainly be in the direction of international or world meteorology and its relation to the phenomena of sun spots and terrestrial magnetism.

" World empire entails world duties, and one of these appears at the present time to be a study of meteorology from the imperial and not solely from the national or parochial standpoint."

In his annual report for 1903 Professor Moore, the Chief of the United States Weather Bureau, refers to the problem of seasonal forecasts for a year, as follows:

It is a difficult piece of science that is involved in the attempt to place the forecasts of the seasons for a year in advance upon a reliable basis, because it may be necessary to take account of several interrelated processes in nature which depend upon the circulation of the atmosphere of the sun and of the earth. The science of meteorology is not to be confined to the atmosphere of the earth, because the changes in the action of the atmosphere of the sun precede the variations in the earth's air, which finally culminate in a certain type of season. Thus, wet and dry seasons, warm and cold summers and winters, and all the other climatic differences first depend upon the persistence of special high and low areas of pressure in one locality or another; these go back to the circulation of the great currents in the atmosphere, which seem to surge back and forth from one side of the earth to the other, or from the oceans to the continents; finally, these currents may be due to the solar radiation, which itself changes with the output of energy from the interior of the sun.

Thus, meteorology is really a very closely allied but difficult branch of solar physics, and it ought to be studied with the aid of a fully equipped observatory devoted especially to such researches. On the sun we count up the number of hydrogen flames or prominences seen on the edge of the disk from day to day, and, from a discussion of the thirty years' record in hand, they are known to vary strongly from year to year. Similarly, the faculæ and spots have their fluctuations in synchronous cycles, and these have been studied for many years. Furthermore, the sun emits energy in the form of radiant light and invisible heat, and by means of suitable spectrum observations the variable amount of this light, and especially the invisible heat, can be registered from day to day and from year to year. The result of these records is to indicate that the sun is in fact a great, variable star, and that terrestrial weather may change in close synchronism with it. There is yet another register of the energy emitted by the sun to be found in the variations of the earth's electrical and magnetic fields, which is perhaps the most sensitive of all, and certainly the most accessible to our measures. The newly discovered action of ions in the atmospheres of the sun and the earth, respectively, which are now believed to be the basis of the electrical and magnetic manifestations, is affording much information upon this obscure subject, and it is full of promise in practical investigations. Langley has announced that the invisible radiant heat energy, as measured in his bolographs, varies from season to season and from year to year. The passage of an eclipse shadow through the atmosphere changes the atmospheric magnetism and electricity in the same way that day and night modify them—by cutting out the sun's rays. In short, the entire field of cosmical processes forms a complex problem which especially concerns the meteorologist, and by him should be studied out for the benefit mankind, whose life and happiness depend so largely upon the weather.

The Weather Bureau is so far convinced of the importance of finding out the laws of this cosmical physics, by which alone the problem can be conclusively solved, that it has been thought proper to found a research observatory at Mount Weather, on the crest of the Blue Ridge Mountains, about 6 miles from Bluemont, Va., and equip it suitably for these investigations. It is evident that such an institution, having its beginning in the early years of the twentieth century, will have an increased usefulness as the years go by if it is organized according to the demands of the best science. It will require fine instruments and able students if it is to command the respect of the scientific world. The subject of solar physics has already grown to such proportions that the British Association for the Advancement of Science has set off a solar-physics section from astronomy and mathematics; the solar-physics observatory at South Kensington, under the able direction of Sir Norman Lockyer, is putting forth valuable results; the solar observations by the Italians for the past thirty years have become invaluable as a basis for these studies; the observatory at Kalocsa, Hungary, and that at Zurich are known to all students for their important publications. Less directly, several of the great astronomical observatories are deriving some of their most valuable discoveries in astrophysics, which is simply another name for stellar meteorology. Thus Potsdam, Paris, Lick, Yerkes, Harvard, and other institutions are working zealously along these lines and filling out the realm of human knowledge in a fashion undreamed of a generation ago.

It may be asked why, with all this wealth of material being secured in other places, it should be important for the Weather Bureau to enter upon these studies as well. The answer is simple. These observatories, for one thing, specialize along certain lines, and it is evident that there should be at least one institutions in the United States where these results are brought together and studied side by side, so that their combined result at any given time can be worked out harmoniously and correlated with the prevailing weather conditions. Furthermore, the publications of these several observatories are issued from the press as much as two to four years after the observations are actually made, so that it is obvious that these late reports can have little value in practical forecasting. We have no intention to enter upon the advanced research problems which rightly belong to specialists, but rather to adapt to the uses of the meteorologist and the forecaster such portions of the well-known types of observatories as seem to be practicable for the immediate uses of the Weather Bureau.

Specifically the plan in mind contemplates the development of an observatory as indicated in the following statement:

(1) An observatory building is in process of erection at Mount Weather, which is well adapted as a school of instruction and for making observations of the ordinary kind with the common meteorological instruments, barometers, thermometers, wind and rain gauges, nephoscopes, theodolites, and actinometers. The first floor is for administration, the second for living quarters, the third for laboratories, and the roof for observing.

(2) Plans are being prepared for a plant adapted to generate large quantities of hydrogen for balloon ascensions, including a shop for the construction of balloons and kites. The ascensions will be limited to about 4 miles in height, our immediate purpose being to measure the temperatures and thermal gradients, which will enable us to construct daily isothermal charts on the two upper planes already described so as to provide isotherms as well as isobars on the high levels. It is proposed to make a complete series of ascensions first at Mount Weather, and afterwards in different portions of the United States, in order to observe the temperature conditions in all classes of cyclones and anticyclones. We may attempt some high ascensions, up to 10 or 12 miles from the ground, when our experience and other conditions warrant, but since storm movements are practically limited to the strata within 4 miles of the ground, the first group of ascensions will be to moderate elevations.

(3) It seems important to install a high-grade bolometer for measuring the invisible solar radiation, which is thought by some students to be largely responsible for the actual temperature of the upper atmosphere. Also a first-class spectro-heliograph is required for keeping a record of the solar prominences, faculæ, and sun spots prevailing at the time of making our weather forecasts. These two instruments are the essentials of an efficient solar physics observatory, and would require the services of an able student of physics to bring out the best results and discuss them efficiently in suitable reports.

(4) These records should evidently be supplemented by an observatory equipped with modern instruments for observations in atmospheric electricity and in magnetism, and we note that a number of valuable new instruments have been invented in recent years which we can use. The special subject of this research is the behavior of ions in the atmosphere as forerunners of weather conditions.

Generally the idea is to bring together for study under one direction the most valuable and practicable observations having a direct bearing on the higher meteorology, which is now engaging the attention of many able physicists and astronomers. In this field are found the best examples of physical and mathematical problems, because it is nature's great laboratory. The atmospheric conditions at Mount Weather are superb, the site being 1,800 feet above the sea level, on a ridge overlooking the wide Shenandoah Valley to the west and the plains of Virginia to the east. An equipment at that place, such as is contemplated, will induce a great scientific activity and generate an intellectual atmosphere highly favorable to the best scholarship. The assistants in charge of the various lines of work will form a strong corps of teachers, who will instruct a new generation of men in the great problems of meteorology, which are destined to occupy the attention of mankind in an increasing ratio with the lapse of time. If the equipment be made up of the very best instruments and able students secured to use them, and especially if patience be manifested in allowing the data to accumulate and be studied in the proper way, an improvement in forecasting for America should be assured. This institution is to be planned for continuous work in the future, and it is not supposed that its effect on forecasting will be immediately manifest because of the difficulty and complexity of the problems involved. One thing is certain, that the founding of such a research institution is the true scientific way to provide for the future, in assurance that the natural difficulties will finally yield to human persistency and intelligence.

In a report to the international committee, Southport, England, 1903, Sir Norman Lockyer presented a most interesting review and discussion of the subject of simultaneous solar and terrestrial changes (Science, Nov. 13, 1903). He called attention to the fact that "there are many cases recorded in the history of science in which we find that the most valuable and important applications have arisen from the study of the ideally useless," and that "long-period weather forecasting, which at last seems to be coming into the region of practical politics as a result of the observation of solar changes, is another example of this sequence." After referring to the knowledge possessed by the ancients of changes in the sun, and to sun spots and a magnetic force which acts upon a needle, which seem to have been known to the ancient Chinese, he passes to more modern inquiries, that date from the times of Galileo and Kepler, which have furnished telescopic observations of the spots on the sun and revealed by spectrum analysis the chemistry of the sun and of its spots, and have also enabled us to study daily other phenomena, the solar prominences, which will in all probability turn out to be more important for practical purposes than the spots themselves.

He quotes from Philosophical Transactions, London, 1801, page 265, an article by Sir William Herschel, which is particularly interesting, not only by reason of the prominence in scientific history of the writer but from the fact that an association of the variation in sun spots with the price of corn and wheat has resulted in popular discussions of the suggestion and misinterpretations of the language and meaning of the author during a period of more than one hundred years. Although Herschel had but little observational data upon which to make comparisons between cycles in the solar changes and the prices of corn and wheat, his argument regarding the influence of the sun on vegetation and his inference that variations in the quantity of light and heat emitted from the sun that are associated with the appearance and disappearance of sun spots were favorable or unfavorable to vegetation have been given respectful consideration by succeeding generations of scientists. The article referred to is as follows:

> The first thing which appears from astronomical observations of the sun is that the period of the disappearance of spots on the sun are of much greater duration than those of their appearance.
>
> With regard to the contemporary severity and mildness of the seasons, it will hardly be necessary to remark that nothing decisive can be obtained. An indirect source of information, however, is opened to us by applying to the influence of sunbeams on the vegetation of wheat in this country. I do not mean to say that this is a real criterion of the quantity of light and heat emitted by the sun, much less will the price of this article completely represent the scarcity or abundance of the absolute produce of the country.
>
> On reviewing the period 1650–1713, it seems probable from the prevailing price of wheat that some temporary scarcity or defect of vegetation has generally taken place when the sun has been *without* those appearances which we surmise to be symptoms of light and heat.
>
> To those acquainted with agriculture who may remark that wheat is well known to grow in climates much colder than ours, and that a proper distribution of rain and dry weather are probably of much greater consequence than the absolute quantity of light and heat derived from the sun, I shall only suggest that those very circumstances of proper alternations of rain and dry weather and wind, etc., favorable to vegetation, may possibly depend on a certain quantity of sunbeams being supplied to them.

About 1870 and 1871, Doctor Meldrum, director of the observatory at Mauritius, concluded that the number of cyclones in the Indian Ocean and the number of wrecks which came into the harbor of Maritius indicated the number of spots on the sun; that, in fact, the maximum number of cyclones was associated with the maximum number of sun spots. In the West Indies Poey found that, as a rule, the maxima of storms fall from six months to two years, at the most, after the years of maxima of solar spots; that out of twelve maxima of storms, ten coincide with maxima of spots, and that out of five minima of storms, five coincide with minima of spots.

CONCLUSIONS.

A review of the foregoing remarks and opinions regarding the application of past and present astronomical and meteorological knowledge to the theory and practice of long-range weather forecasting leads to the following conclusions:

1. That systems of long-range weather forecasting that depend upon planetary meteorology; moon phases, cycles, positions, or movements; stellar influences, or star divinations; indications afforded by observations of animals, birds, and plants, and estimates based upon days, months, seasons, and years have no legitimate bases.

2. That meteorologists have made exhaustive examinations and comparisons for the purpose of associating the weather with the various phases and positions of the moon in an earnest endeavor to

make advances in the science along the line of practical forecasting, and have found that while the moon, and perhaps the planets, exert some influence upon atmospheric tides, the influence is too slight and obscure to justify a consideration of lunar and planetary effects in the actual work of weather forecasting.

3. That the stars have no appreciable influence upon the weather.

4. That animals, birds, and plants show by their condition the character of past weather, and by their actions the influence of present weather and the character of weather changes that may occur within a few hours.

5. That the weather of days, months, seasons, and years affords no indications of future weather further than showing present abnormal conditions that the future may adjust.

6. That six and seven day weather periods are too ill-defined and irregular to be applicable to the actual work of forecasting.

7. That advances in the period and accuracy of weather forecasts depend upon a more exact study and understanding of atmospheric pressure over great areas and a determination of the influences, probably solar, that are responsible for normal and abnormal distributions of atmospheric pressure over the earth's surface.

8. That meteorologists are not antagonistic to honest, well-directed efforts to solve the problem of long-range forecasting; that, on the contrary, they encourage all work in this field and condemn only those who, for notoriety or profit or through misdirected zeal and unwarranted assumptions, bring the science of meteorology into disrepute.

9. That meteorologists appreciate the importance to the world at large of advances in the period of forecasting and are inclined to believe that the twentieth century will mark the beginning of another period in meteorological science.

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